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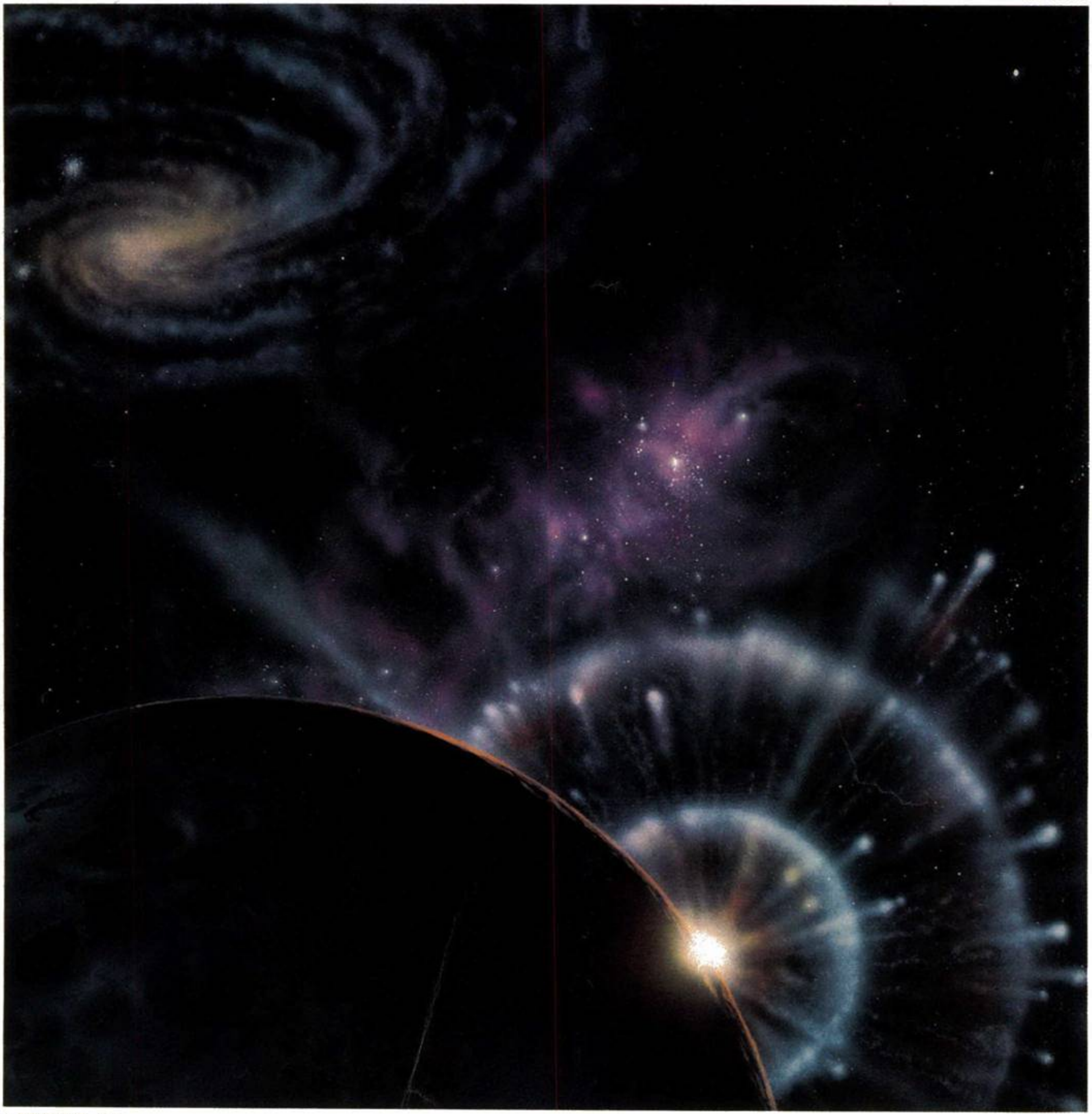

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Close-up of Supernova 1987A

Meade 10" Model 2120/LX6. Shown with optional Digital Readout System and Superwedge.

Background photo: The Lagoon Nebula (M8). A 20-minute exposure with the Meade 8" Model 2080/LX6.

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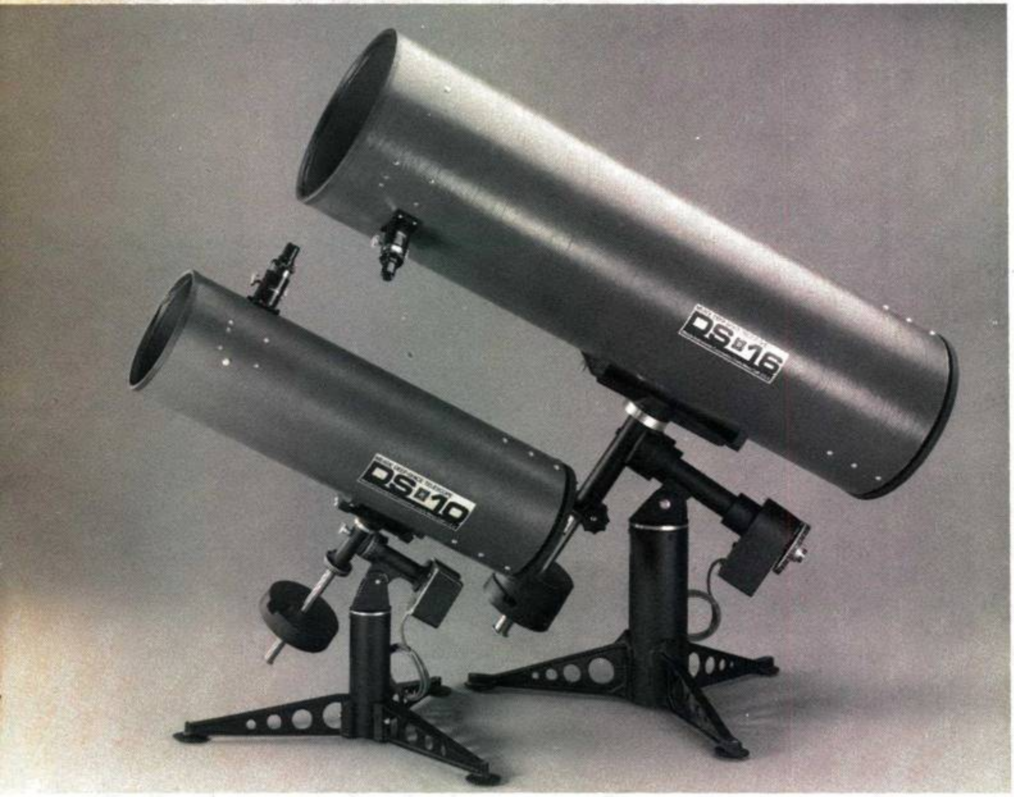

Meade DS-10 and DS-16, shown with optional motor drives, setting circles, giant focusers.

Meade DS-16 Astrophotos:
(top) Southern region of the Andromeda Galaxy (M31);
(lower) The Horsehead Nebula. Both photos by Paul Roques.

Dealer Locations and Assistance

For your nearest Meade dealer location, or for free telescope information and assistance, call Meade Instruments toll-free from anywhere in the continental U.S.A. (except California): **1-800-854-7485.** From all other areas, including California, call direct (714) 556-2291.

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ON THE COVER: A massive blue star glows two thousand times brighter than before, illuminating a region in the Large Magellanic Cloud. In the distance lies the Milky Way Galaxy, where 170,000 years after the explosion human beings will first see the light from supernova 1987A. (See page 20.)

STARS, GAS, AND DUST form a graceful spiral pattern in galaxy M81 in Ursa Major. Photo by Tony Hallas and Daphne Mount.

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Behind the Scenes

PLANETARY EXHILARATION

As you read these words, *Voyager 2* is about to encounter Neptune and Triton. As the flyby has drawn closer, ASTRONOMY has traced *Voyager*'s progress, bringing you interviews with the scientists who are now preparing to explore two new worlds, to discover who-knows-how-many new satellites, and to uncloak the mysteries of Neptune's ring arcs.

This month we present the most recent images available at press time. In upcoming issues we will provide in-depth coverage of discoveries from *Voyager*, plus a complete portfolio of the magnificent images *Voyager*'s cameras will take during the encounter with Neptune.

While you watch the nightly news from Neptune, reread our background stories on Triton, the ring arcs, and Neptune. These appeared in the February, May, and August issues of ASTRONOMY. Judge for yourself whether the best pre-encounter guesses planetary astronomers made turn out to be right — or whether Neptune still has a few unexpected treats in store.

As the *Voyager* mission moves toward a conclusion, we report on two new missions. In May, the *Magellan* mission to map Venus by orbital radar left Earth orbit on a fifteen-month journey to Venus. Our story begins on page 38. And come December, the shuttle will lift the *Galileo* spacecraft into orbit (finally!) and send it on its roundabout way to Jupiter. Turn to page 44 for a look into the history of that long-delayed mission.

To bring you our report on the Soviet *Phobos* mission, Robert Burnham interviewed American space scientists who are working with Soviet scientists to analyze and interpret data from *Phobos*' cameras and infrared scanners. Soviet scientists are now remarkably open with their results. However, because the Soviet Union has not yet officially released them, we cannot bring you all the neat images *Phobos* obtained at Mars. Watch for them in a future issue of ASTRONOMY.

Of course, the action in this issue is not confined to planetary astronomy. The detection of the pulsar in supernova 1987A — still somewhat in doubt as I write — forges a vital link in the chain of reasoning that underlies modern astronomy's prediction of neutron stars, black holes, and the exotic cosmologies that currently describe the origin of the universe.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

No Nukes in Space

This letter answers "We Need Nuclear Power in Space" by John Casani (Viewpoint, June 1989). Mr. Casani states that he is "grateful" that the public supports the need for nuclear power to fulfill NASA's charter to explore the solar system.

Our organization, the Florida Coalition for Peace and Justice, represents thousands of concerned Floridians and does not support the use of plutonium 238 as a fuel source on the upcoming *Galileo* and *Ulysses* missions. We are organizing to stop the missions until public hearings can be held throughout Florida. We believe the public has the right to be properly informed about the potential risks to our lives that an accidental release of plutonium 238 could cause.

It is our belief that the launch of plutonium onboard *Galileo* will serve as a way to further desensitize the public into believing that nuclear power in space for future military efforts would be safe and acceptable.

It is clear to us that the military essentially runs the show at NASA and that nuclear power proponents control the Department of Energy, the agency that plays an important role in determining the kind of power sources to be used on interplanetary space probes.

As the public learns more about this issue, we believe they will demand that the question be studied long and hard before we launch nuclear power of any kind into space. After the *Challenger* and Chernobyl accidents, we have learned that the optimistic predictions of scientists, the nuclear industry, and politicians can be wrong.

The time has come for the public to become involved in the issue — even if it slows down plans for interplanetary exploration. After all, that's what democracy is all about. — *Bruce K. Gagnon, State Coordinator, Florida Coalition for Peace and Justice*

Asteroid Nominations

I think it is time for asteroids to be named after President John F. Kennedy and Robert F. Kennedy. The United States has designated special days to honor other important figures, but there is nothing to remember either of these two great men.

I am not sure who to contact, but I believe the time has come to recognize the contributions of these men. —*Michael Boschat, Halifax, Nova Scotia*

— There is a policy for naming asteroids established by the International Astronomical Union (IAU). The discoverer of the asteroid submits a name to the

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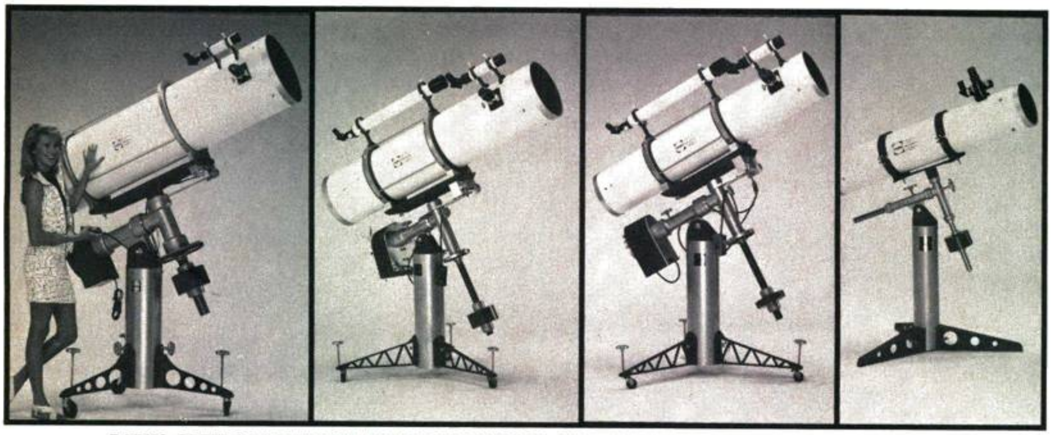

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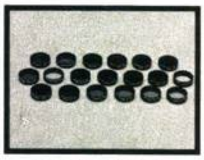

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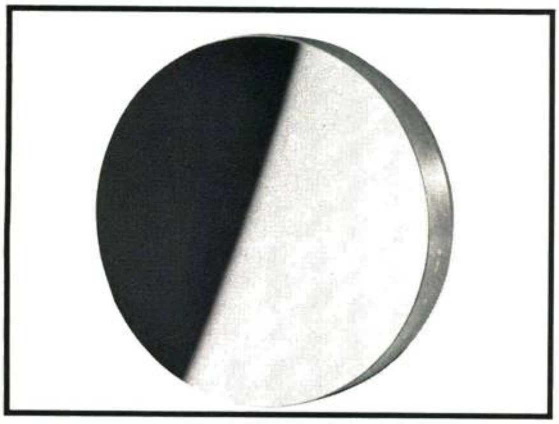

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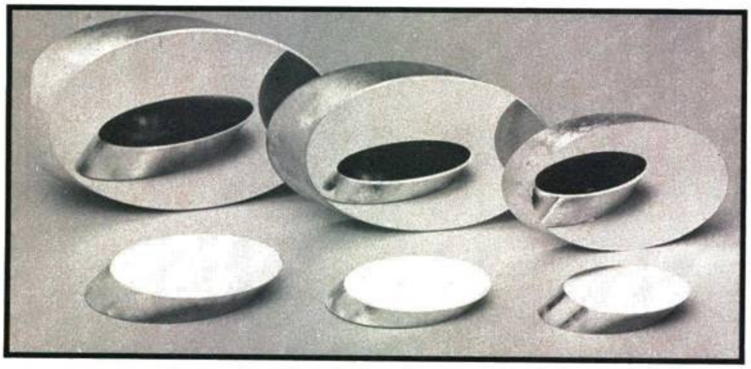

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IAU. An IAU committee then approves or rejects the name. If the asteroid is being named after a political figure, the person must be dead for one hundred years to be considered.

This rule came about because a western astronomer named an asteroid after the Soviet dissident Andrei D. Sakharov; the Soviets, in turn, began naming asteroids after prominent American Communists. To avoid this type of politicizing, the IAU has established these guidelines for naming asteroids.

Save the Space Station

After reading "Space Station in the Balance" by Stephen Cole (May 1989), I realized that if the Space Station does not get off the ground, the United States will be forever behind other countries in the area of space exploration and the accompanying technology.

There is much to be gained in having a space station — advances in the fields of medicine, meteorology, and metallurgy, to name a few. The benefits of the Space Station far exceed the price tag attached to it. I urge people to back the plan and challenge bureaucrats to put the plan into action. Write to your congresspersons and tell them you support the Space Station. America's future in space depends on your support. — *Lee Martin, Greenwich, Ohio*

The Fate of 12 Sagittarii

In response to my article "The Mystery Stars in Sagittarius" (July 1988), I received an inquiry about why 12 Sagittarii is referred to in modern catalogs as AP Sgr without its Flamsteed designation.

Over 150 years ago, Francis Baily pointed out that after Flamsteed observed 12 Sgr, he made an error in precessing the star's position to epoch 1690 (the epoch of his *British Catalogue*).

When subsequent astronomers and cartographers found no star matching Flamsteed's description at the coordinates he listed, they dropped his number. In the nineteenth century, F. W. A. Argelander, editor of the *Bonner Durchmusterung*, proposed designating variables with Roman capital letters. Hence, 12 Sgr became AP Sgr. — *Morton Wagman, Brooklyn, New York*

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity. □

Viewpoint

DO WE HAVE A PLACE IN SPACE?

by Harry L. Shipman
Professor of physics at the University of Delaware and author of Humans in Space *(Plenum Press, 1989).*

Many space enthusiasts see the journey into space as the next logical step in a human venture of exploration and discovery that began five hundred years ago in the time of Christopher Columbus. Many authors who write about the space program seem to think that space colonization is inevitable. In their view, space must be settled in the twenty-first century in the same way that Europe occupied and settled America a few centuries ago.

While there is an exploring spirit, a desire to go where no human has ever gone before, this spirit has never been the sole reason that humans have ventured forth into unknown oceans. What we do depends on whether space exploration is purely government-funded science or whether it is commercial, and whether keeping human beings alive in space will always be as expensive as it is now.

> **If history is any guide, space settlement must pay off in practical terms if it is to occur.**

If history is any guide, space settlement must pay off in practical terms if it is to occur. It may be too expensive, too pointless, or both to send people into space; in that case, we may just launch robot mines, factories, and laboratories into space, with people playing a more secondary role.

Realistically, space settlement is not inevitable. It's very expensive to live in space, if we support astronauts in the way that the major space powers do now. There is, however, a way around the high-cost dilemma. If air and water can be extracted or captured from other bodies in the solar system and used by human beings, the resource requirements for space colonization would plummet precipitously.

The cost of settling and using space is only one side of the usual cost/benefit consideration that enters any human decision. What are the benefits? Increased knowledge and a sense of adventure are there, to be sure, but the history of human exploration of Earth demonstrates that exploratory ventures with some potential for commercial return are likely to be far more vigorously pursued than ventures that are undertaken for the sake of science alone.

Whether we human beings settle the inner solar system depends on the answers to three critical questions:

- Can the air and water needed to support human life be found or extracted from extraterrestrial bodies, or do these have to be transported into space from Earth?
- Will space commerce develop beyond the communications satellite business and what is the nature of commercial opportunities in space?
- Do we, as a nation, have the courage to make the effort needed to explore and, if possible, settle outer space?

Space enthusiasts assume that the answer to all three questions is an unequivocal, resounding "yes." If these positive answers pan out, they lead to optimistic pictures of lunar bases, space settlements, outposts on Mars, and other ideas that would have seemed like science fiction fifty years ago. However, positive answers to these questions are not inevitable.

If extraterrestrial materials can be used to support life, and if space commerce becomes a reality, then, and only then, is it likely that human beings will settle at least some parts of the inner solar system. If life support continues to require large transfusions of material goods from Earth, then the human role in space will be far more limited. In such a case, space industrialization could still happen, leaving us with a scenario in which space would be "settled" by robots.

Another possibility is that space industrialization also won't happen, leaving space to the space scientists. Space science doesn't require the presence of humans in space, and some of NASA's most spectacular achievements have been in the area of using space to extend the frontiers of human knowledge.

But there is a third question that lies in the background of all this: Do we have the political will to make the substantial investment of human and financial capital in order to realize any of these possibilities? The establishment and continuation of a space exploration program requires a tremendous investment of courage, energy, and resources. We may have the technological ability to establish outposts on the Moon and send human beings to Mars, but do we have the courage to implement our vision? □

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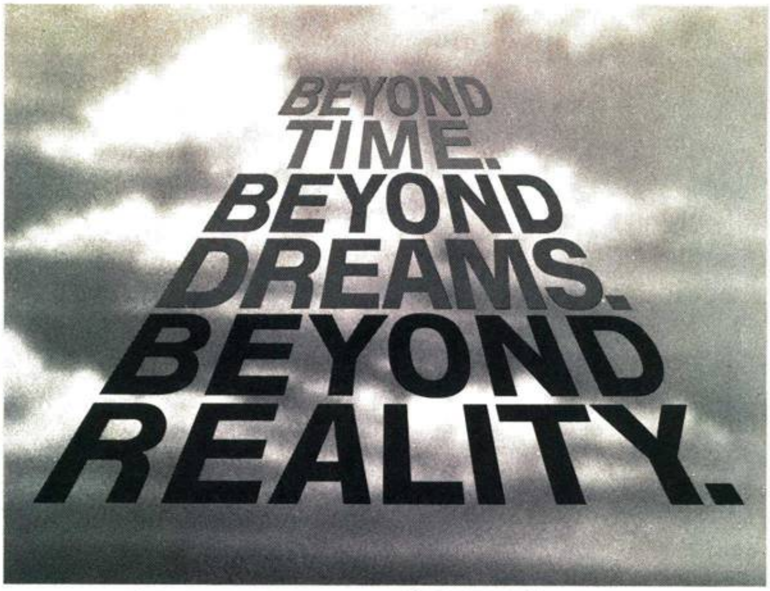
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NEW BROWN DWARF EVIDENCE LOOKS PROMISING

Observations of a young star-forming region in the constellation Taurus have yielded nine objects that may belong to an elusive class of failed stars known as brown dwarfs. If the discovery is confirmed, brown dwarfs might account for a fraction of the "missing mass" in the universe.

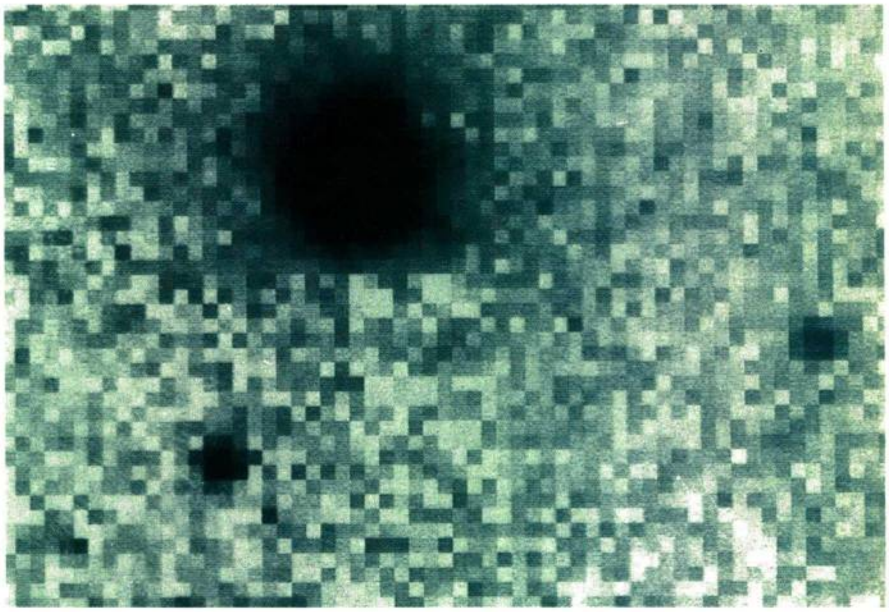
Brown dwarfs are thought to be stillborn stars with masses ranging from a few Jupiters up to eighty Jupiters. They aren't full-fledged stars because they don't shine by the steady nuclear burning of hydrogen, and they aren't planets because they didn't condense from matter encircling a newborn star. Brown dwarfs lose their brightness faster than true stars, which makes them very difficult to uncover. (See "Do Brown Dwarfs Really Exist?" by Deborah Byrd, April 1989.)

The discovery was announced by William Forrest of the University of Rochester at the June meeting of the American Astronomical Society in Ann Arbor, Michigan. Forrest and his colleagues studied twenty-five stars in a region known as the Taurus-Auriga star-formation association using the University of Rochester's infrared camera at the NASA Infrared Telescope Facility (IRTF) on Mauna Kea in Hawaii. Eleven of these stars have twenty possible companions, nine of which display red colors characteristic of cool stars and of brown dwarfs. Their masses range from five to fifteen Jupiter masses.

Moreover, preliminary evidence suggests that these objects are "free floating" through space, that is, they are not gravitationally bound to other stars. Statistically, there could be from ten thousand to a million of these objects in the Taurus region alone.

This is not Forrest's first discovery of brown dwarf candidates. In June 1988, he and several colleagues reported finding a low-mass object, Gliese 569B. Questions about the object's age complicated the analysis of the data, however, and Forrest now thinks that there may be only a 50-50 chance that the object is a brown dwarf. A few more decades-worth of observations of the object's motion and age are needed to determine whether Gliese 569B is merely a low-mass star or a brown dwarf, Forrest said.

"We learned from the first time," Forrest said. "This time we chose to study stars of a known age," which, in this region, average about one million years old. "When we decided to 'think young' we were almost assured of success."



THE TWO OBJECTS below the bright star on this infrared image are believed to be brown dwarfs, each with a mass of less than twenty Jupiters.

Astronomers believe brown dwarfs may comprise part of the deficit of the missing mass of the universe. Current theories indicate the universe's total mass should be about ten times greater than the mass that has actually been measured. Galaxy clusters, for example, do not appear to contain enough visible mass to gravitationally bind them together; yet over the age of the universe, they have remained intact.

If the nine candidates turn out to be low-mass companions to stars, then the objects will account only for a small fraction of the missing mass. But if they're not companions, Forrest said, this would indicate that brown dwarfs are far more numerous, occupying star-poor as well as star-rich regions, and thus could account for much of the missing mass.

One way of confirming whether or not these objects are brown dwarfs is to prove that they are true members of the Taurus star-forming association rather than merely low-mass stars positioned along our line of sight. Studies of the motions of six of Forrest's candidates by Lick Observatory astronomer Burton F. Jones indicate that four are moving with the Taurus association, making it likely that they are members. Forrest, however, wants additional proof.

"More confirmation besides proper motion is needed to put these bodies in Taurus," he said. "We need more confirming evidence, such as [that gleaned from] spectroscopy.

"All previous cases — even Gliese 569B — have been borderline cases. But these are not borderline. If they're true Taurus members, they're brown dwarfs. It's cut and dried. The issue of true membership will settle it."

JUPITER'S MOON IO HAS HYDROGEN SULFIDE FROSTS

Hydrogen sulfide, the "rotten eggs" gas you get when the refrigerator turns leftovers into biology experiments, has been found to exist in the form of frost on the surface of Jupiter's moon Io. Scientists had long suspected that Jovian protons bombarding Io's sulfur-rich surface created the substance, but this finding is the first time it has been identified in the solar system except on Earth.

Writing in the April 28 issue of *Science*, Douglas Nash of the Jet Propulsion Laboratory and Robert Howell of the University of Wyoming performed laboratory experiments with mixtures of sulfur dioxide, already known to exist as frost on Io's surface, and hydrogen sulfide. By varying the proportions of the two substances, Nash and Howell were able to match a spectral feature that has been

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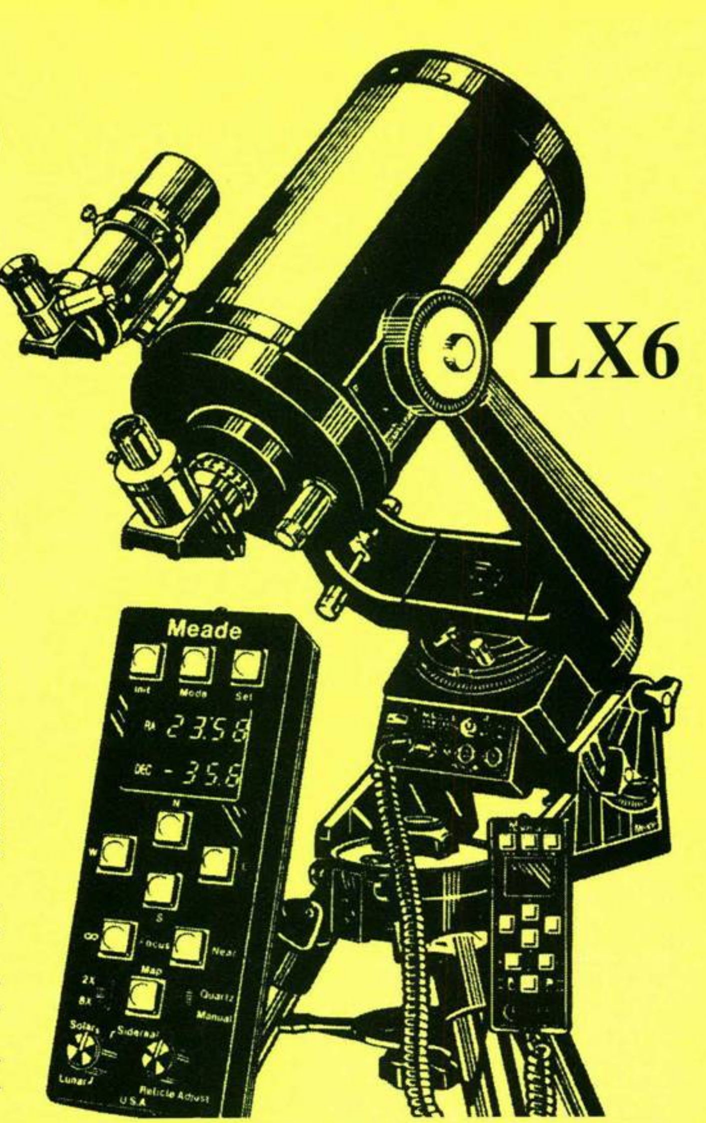

Meade's new LX6's boast an *f*/6.3 optical system which permits astrographic exposures in only four-tenths of the time required by an *f*/10 system! In addition, they come complete with quartz-locked, micro-computer-controlled, electronic pulse-motor drive, sophisticated hand control unit with astrographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces, giant 9x60mm finderscope, built-in provision for optional digital readouts or CAT system, and much more!

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2080 LX6	(List: $ 4,400)	CALL
2120 LX6	(List: $ 6,400)	CALL
Optional Digital Readout System:		
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2120 LX6 *with* Mod. 9070	(List: $6,990)	CALL

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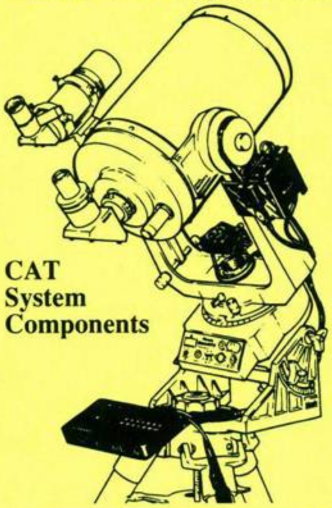
Meade's Computer-Aided Telescope System

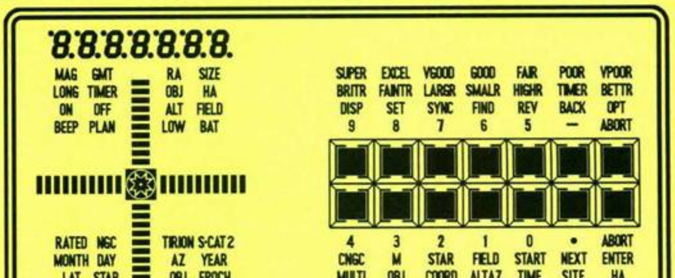


CAT System Components

Meade's Computer-Aided Telescope (the "CAT") system has most of the advantages of a computer-controlled telescope at only a fraction of the cost. Consisting of a specially-designed, high-speed, extremely powerful computer, along with a pair of high-resolution incremental shaft encoders and their associated mounting hardware, drive components and cabling (*see general arrangement drawing at left, and panel layout drawing at right*), the CAT can readily and quickly direct you to any of the thousands of celestial objects whose coordinates and other descriptive information are permanently stored in its 1Mb plug-in EPROM database, ***including all of the planets***, as well as to any other celestial object of known coordinates (comets, asteroids, quasars, super-novae, etc.). The computer is loaded with extra features and functionality as the panel legends, at right, indicate.

For the computer-literate, there is also a version of the CAT available with an RS-232C port (the "CAT-COM") for connection to a "PC" compatible personal computer. CAT-COM includes four "demonstration" software subroutines, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software is supplied on a 5.25" 360Kby diskette, with backup source-code listings in the instruction manual.

The CAT is available for most fork-mounted Schmidt-Cassegrain telescopes, but has been ***electronically integrated*** with the new LX6 series, so that the encoders and the CAT computer plug directly into the drive-base. Consequently, during our introduction of the LX6 series telescopes, we are offering extra savings on packages consisting of an LX6 telescope and one or the other of the CAT systems.



Optional Computer-Aided Telescope (CAT) System:		
CAT *for* 2080 *or* 2120 LX6	(List: $1,990)	CALL
CAT-COM *for* 2080 *or* 2120 LX6	(List: $2,290)	CALL
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2080 LX6 *with* CAT-COM	(List: $6,690)	CALL
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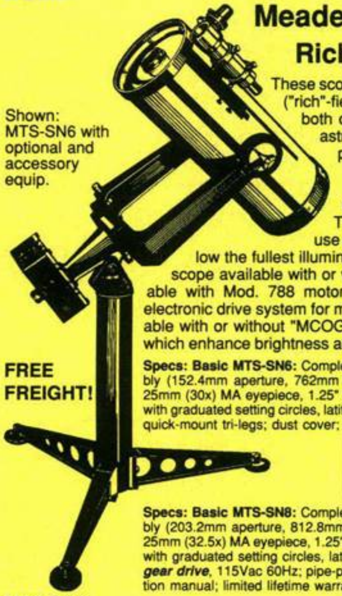

Shown:
MTS-SN6 with optional and accessory equip.

These scopes' wide, bright, highly corrected fields of view ("rich"-fields) and "fast" focal ratios make them ideal for both deep space visual observing and prime focus astrophotography. Easy and convenient to transport and use because of their "fork" -type equatorial mounts, they are excellent all-around scopes for those just starting in astronomy, as well as for experienced astrophotographers. Their 1.25"/2.00" focusers not only permit the use of the greatest variety of eyepieces, but also allow the fullest illumination of the film-plane during photography. 6" scope available with or without Mod. 788 motor drive. 8" scope available with Mod. 788 motor drive, or "LX3" quartz-synchronized micro-electronic drive system for maximum accuracy and precision. All are available with or without "MCOG" (multi-coated optics group) optical coatings, which enhance brightness and contrast of visual and photographic images.

FREE FREIGHT!

Specs: Basic MTS-SN6: Complete 6"A, f/5 Schmidt-Newtonian telescope tube assembly (152.4mm aperture, 762mm focal length); 2" helicoid focuser, with 1.25" adapter; 25mm (30x) MA eyepiece, 1.25" barrel; rugged dual-fork equatorial astronomical mount with graduated setting circles, latitude adjustment, and latitude scale; pipe-pier stand with quick-mount tri-legs; dust cover; instruction manual; limited lifetime warranty.

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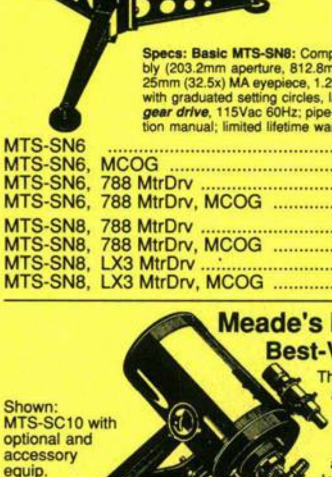

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MTS-SC8, 788 MtrDrv	(List: $ 1,800)	CALL
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MTS-SC8, LX3 MtrDrv, MCOG	(List: $ 2,240)	CALL
MTS-SC10, 788 MtrDrv	(List: $ 2,780)	CALL
MTS-SC10, 788 MtrDrv, MCOG	(List: $ 2,950)	CALL
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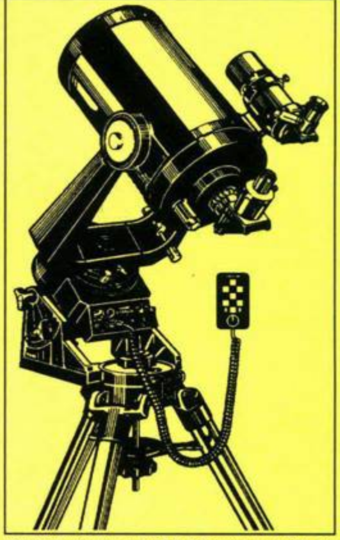
Meade's LX5's



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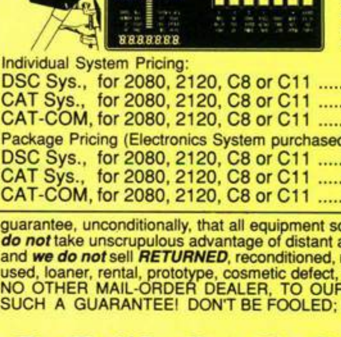

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CAT Sys., for 2080, 2120, C8 or C11	(List: $ 1,990)	CALL
CAT-COM, for 2080, 2120, C8 or C11	(List: $ 2,290)	CALL

Package Pricing (Electronics System purchased at same time as its telescope):

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CAT Sys., for 2080, 2120, C8 or C11	(List: $ 1,990)	CALL
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observed telescopically at 3.914 micrometers in Io's infrared spectrum. The best match came when the scientists condensed a thin layer of hydrogen sulfide onto a much thicker stratum of sulfur dioxide.

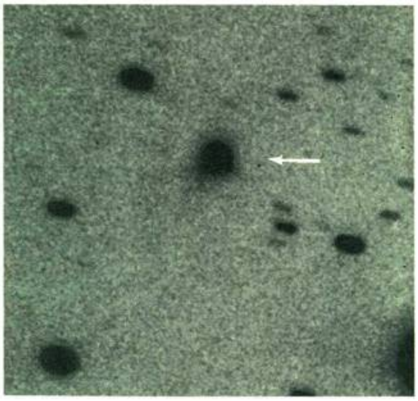
Telescopic observations show that the infrared feature comes and goes as Io circles Jupiter and its surface alternately dives into Jupiter's shadow or emerges from it. The feature's strength also varies from one orbital circuit to the next; therefore, scientists believe the hydrogen sulfide condensation is spotty but could occur over much of the moon's surface.

CHIRON BECOMES A COMET

The minor planet Chiron, which orbits between Jupiter and Uranus, is developing a lopsided gassy coma as it moves closer to the Sun. This result confirms the suspicions of many astronomers who thought that Chiron was really a comet and not the minor planet it was classed as when discovered in 1977. Karen Meech of the University of Hawaii and Michael Belton of Kitt Peak National Observatory observed the shell of gas on April 9, 1989, with Kitt Peak's 4-meter telescope. (Chiron, by the way, should not be confused with Charon, the moon of Pluto.)

For the last year and a half, astronomers have been watching Chiron brighten more than simple distance could account for as it comes in toward perihelion, which it will reach in 1995. In February 1988, David Tholen of the University of Hawaii, William K. Hartmann of the Planetary Science Institute, and Dale Cruikshank of NASA's Ames Research Center were the first to establish Chiron's anomalous brightening using infrared observations that showed the object was twice as bright as a surface of bare rock or rubbly regolith should be. They guessed that a dusty, infrared-bright coma was forming around Chiron as it warmed up, but until Meech and Belton observed the coma directly there was no proof.

Chiron is about 180 kilometers in diameter, spins once every six hours, and has a grayish surface with bright and dark patches. Chiron was classified as a minor planet in 1977 because it showed no cometary activity then, and its orbit, while at an unusual distance from the Sun, *did* not resemble the orbits of most comets. Perhaps the largest comet known, Chiron is primarily made up of water, carbon compounds, and fine silicate dust.



THE COMA PROVES THE COMET as former minor planet Chiron reveals its true nature. The CCD image reveals a faint comet tail extending to the lower left of Chiron (arrow).

The coma observed by Meech and Belton is probably not the result of evaporating water ice because the temperature at Chiron's distance from the Sun (about 12 astronomical units) is too low; more likely, carbon dioxide ice is responsible. At discovery, the coma extended southeast from Chiron about 5 arcseconds, which translates to a minimum extent of about 40,000 kilometers. (It could be larger, depending on perspective effects.) Chiron's magnitude at the time was roughly 16.5.

At perihelion Chiron will lie 8.5 astronomical units from the Sun; its aphelion distance is 18.8. Chiron thus swings from between Jupiter and Saturn out nearly to Uranus. Due to gravitational perturbations, mainly by Saturn and Jupiter, its orbit is unstable over the long term, and someday Chiron may come closer to the Sun — or be flung out of the solar system.

A SMOOTH TRANSITION TO A LUMPY UNIVERSE

One of the sharpest thorns in the sides of galaxy formation theorists is the unvarying temperature of the cosmic background radiation (CBR), the afterglow of the Big Bang that pervades the universe even today. Though it is an observational keystone of the Big Bang model, the CBR's uniformity frustrates theorists who must explain how galaxies came to exist without leaving their spectral "tracks" in the CBR's smoothness.

The best measurements attained so far — accurate to better than a few parts in 100,000 — show that the 3-kelvin CBR is the same in all directions. (Our solar system's motion through the CBR at about 400 miles per second makes the CBR appear slightly hotter in one direction than in the opposite direction. But when this motion is subtracted out, the temperature is essentially invariable.) This uniformity implies a uniform universe. And yet the universe consists of billions of stars and galaxies, not to mention vast regions apparently devoid of galaxies — clear evidence that the universe is *not* uniform at every scale.

David N. Schramm of the University of Chicago and his colleagues believe they may have a solution to this paradox. They suggest that a million or so years after the Big Bang, matter in the universe underwent a fundamental change in state — a phase transition — from which slight "bumps" developed in the smooth distribution of matter. Although a cosmological phase transition is not a new concept, Schramm's idea about when this event occurred patently conflicts with most galaxy formation theories, which maintain that a phase transition occurred an instant after the Big Bang.

A phase transition occurs when matter undergoes a sudden change in state. In the everyday world, liquid water undergoes a phase transition when it freezes or boils. Such a dramatic change in matter is brought on by an alteration in the arrangement of atoms.

In the early universe, a phase transition occurred when the radiation filling the universe "froze out" into matter as the universe cooled. But just as ice freezes unevenly — forming sheetlike or filamentary defects in the ice crystal — the primordial matter froze out unevenly, generating density ripples that eventually developed into galaxies and galaxy clusters.

In fact, said Schramm, there could have been more than one phase transition. "Every time forces drop out of equilibrium," said Schramm, "you go through some sort of phase transition. So as the universe goes from having all four fundamental forces unified to three out of four unified, you have a phase transition, and so on down the line."

Schramm and his colleagues believe a late phase transition explains how galaxies formed without disturbing the background radiation: The disturbances that eventually grew into galaxies occurred after the CBR formed. One million years after the Big Bang, the universe was cool enough to allow electrons and protons to combine to produce hydrogen atoms, but by then, the electromagnetic energy had smoothed out. Thus, by the time galaxies enter the scene, the CBR has already been established.

The sheetlike defects that form during a late phase transition can also be used to explain the large-scale foamy structure of the universe that has been observed by

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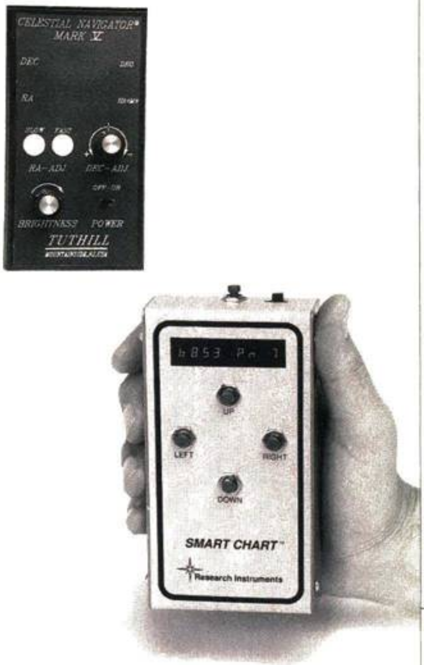

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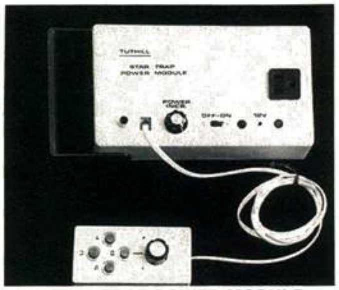

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astronomers in certain sectors of the sky. In models featuring an early phase transition, these same defects would have produced large fluctuations in the CBR, fluctuations that are not observed today.

"We were amazed at all the problems [a late phase transition] solves," said Schramm. "People have been continually beating their heads against the wall going in one direction. What we've essentially done is run around the wall."

FIVE-METER TELESCOPE REACHES DIFFRACTION LIMIT

Astronomers at Palomar Observatory have cleanly split two very close double stars using a technique adapted from radio astronomy. Two stars — Beta Coronae Borealis and Sigma Herculis — served as guinea pigs in the experiment. They have angular separations of 0.230 arcseconds and 0.070 arcseconds, respectively. The stars were split on nights when atmospheric seeing at the telescope was between 1 and 2 arcseconds.

The team of California Institute of Technology astronomers, led by Tadashi Nakajima, used the 5-meter telescope to simulate an array of small telescopes, analogous to an array of small radio telescopes. With radio telescopes, astronomers combine signals from a large number of antennas into an image with as much detail as a single gigantic antenna would show.

After the 5-meter mirror combined light from the array of small apertures into a single image, the astronomers recorded the starlight with an image sensor capable of registering single photons. From the resulting interferometric images, the team then computed what an ideal 5-meter telescope would see, using software originally developed for very long baseline radio astronomy.

The imaging technique, called aperture synthesis, has been used by radio astronomers for many years to make sharp pictures of distant radio sources. In effect, the 5-meter telescope behaved just like an array of 6-inch telescopes separated by several meters, and the result was far sharper pictures than the telescope can normally produce.

The achievement is the culmination of a three-year effort to obtain diffraction-limited images with the 5-meter telescope. It demonstrates the potential of optical aperture synthesis to produce extremely sharp images with ground-based telescopes. This work points the way toward an optical interferometric telescope array analogous to the Very Large Array radio telescope.

Space News

SOVIET STATION PROBES THE UNIVERSE

For more than three years, the Soviet space program has been doing what NASA can only dream about: operating a manned space station. Since its launch in February 1986, the Soviet *Mir* station has slowly grown in size and now includes an entire observatory module devoted to studying the universe from space.

An astrophysical observatory module named *Kvant* (Russian for quantum) was launched in April 1987. *Kvant* carries a variety of telescopes designed to observe astronomical objects emitting x-rays and ultraviolet light. The telescopes are attached to the outside of the module and are controlled by a cosmonaut inside the module's pressurized compartment.

To point the telescopes at an object, the entire space station complex rotates using six large, electrically powered gyroscopes that maintain the correct position while *Kvant*'s telescopes are observing. The pointing accuracy is about 1 arcminute, which is more than ten times better than its designers had expected.

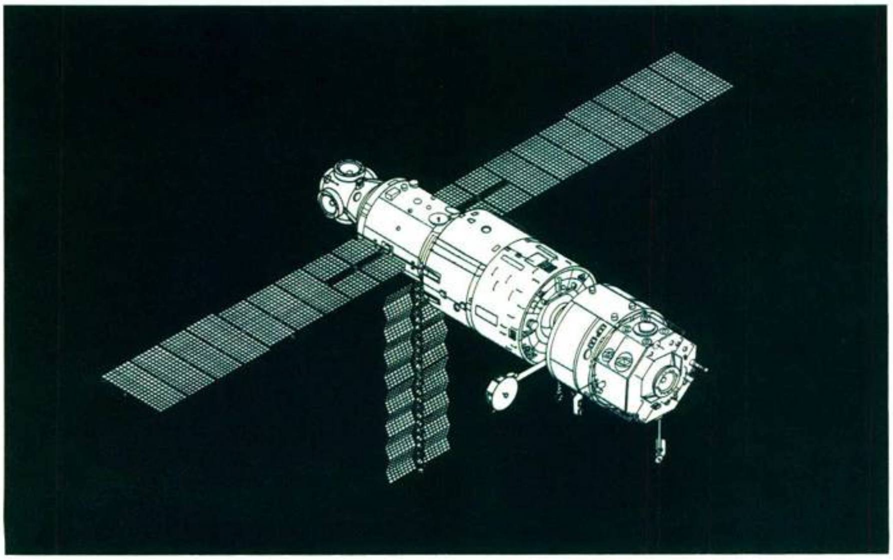
The astronomical instruments aboard *Kvant* include the Roentgen observatory with its four x-ray telescopes and the Glazar ultraviolet telescope. The Roentgen was developed and manufactured by the European Space Agency and space organizations in West Germany, Holland, and Great Britain.

The Glazar ultraviolet telescope uses a 40-centimeter-diameter mirror and records images on film with the help of an image intensifier. Developed jointly by Soviet and Swiss scientists at the USSR's Byurakan Observatory, Glazar's primary objective is to conduct ultraviolet surveys of stars, galaxies, and quasars.

The Roentgen and Glazar instruments allow scientists to conduct wide spectral surveys of a variety of targets over a long period of time. Targets observed so far include a possible neutron star in Cygnus, x-ray sources in Centaurus and Hercules, and ultraviolet sources in the Andromeda Galaxy. *Kvant* has also observed an extremely intense x-ray source in Vulpecula that arose quite unexpectedly.

One target in particular has received a lot of attention: supernova 1987A. The supernova exploded in February 1987, just two months before *Kvant* was launched. By June *Kvant* had been checked out and ready for operations, just in time to record the first burst of x-rays from the supernova.

Observing 1987A soon became the dominant activity onboard the space station. Glazar began making ultraviolet observations of the supernova to complement the observations made by the x-ray telescopes. The combined data from both instruments has provided valuable



THE MIR STATION measures 55 feet; the *Kvant* module is located at the near end of the station.

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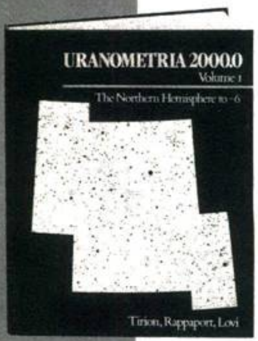
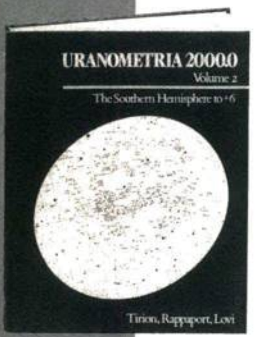
by Wil Tirion, Barry Rappaport, and George Lovi





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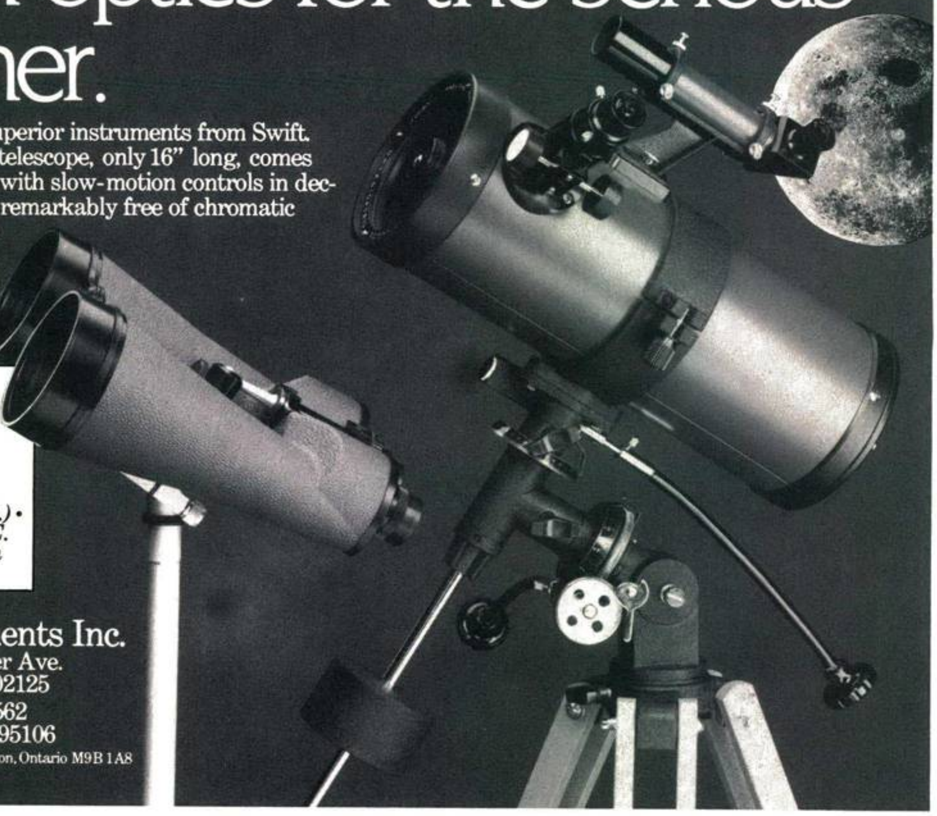

information for scientists trying to understand supernovae and the high-energy processes associated with them.

Some of the fruits of *Kvant*'s supernova observations include a profile of the intensity of 1987A's x-ray radiation over time. This data allowed astronomers to determine that 1987A's expanding shell of gas is riddled with radioactive cobalt distributed over a very large volume. The drastic decrease in 1987A's hard x-rays observed last December is probably due to the ever-decreasing amount of cobalt.

Kvant has had its share of problems, however. Within six months of its launch, one of *Kvant*'s telescopes malfunctioned and a long spacewalk by cosmonauts was required to repair it. The job was made doubly difficult because the telescope was not designed for repairs once in orbit, a feature shared by *Kvant*'s other instruments.

On April 27, the cosmonauts aboard *Mir* returned to Earth, leaving the space station vacant for the first time in two years. Ostensibly the reason for this is budget problems within the Soviet space program, but some sources suggest the Soviets are having technical problems with *Mir*, in particular a serious shortage of electrical power. A repair mission is planned for August. — *Michael Engle*

NASA ANNOUNCES NEW SHUTTLE LAUNCH DATES

The space shuttle launch schedule has undergone its first major revision since flights resumed last year. The three shuttle orbiters are scheduled to fly ten missions in the coming year, including a number of astronomical missions.

The launch schedule through October 1990 is as follows:

October 12, 1989, the *Galileo* mission to Jupiter;

November 19, 1989, a Department of Defense mission;

December 18, 1989, launch of a communications satellite and retrieval of the Long Duration Exposure Facility;

February 1, 1990, a Department of Defense mission;

March 26, 1990, the *Hubble Space Telescope*;

April 26, 1990, ASTRO-1 astronomical observatory mission;

June 4, 1990, the *Gamma Ray Observatory*;

July 9, 1990, a Department of Defense mission;

August 16, 1990, Space Life Sciences Laboratory 1 mission;

October 5, 1990, the *Ulysses* spacecraft to study the Sun.

Amateur News

A BIG YEAR FOR RIVERSIDE

Sunny days and clear nights brought record crowds to the twenty-first meeting of the Riverside Telescope Makers Conference, held on Memorial Day weekend in the mountains near Big Bear, California. An estimated 2,800 amateur astronomers converged on the Camp Oakes site, drawn by over one hundred telescopes on display, the famous Riverside swap-meet, bargains and show specials from the commercial telescope exhibitors, plus talks, papers, and the friendly atmosphere and camaraderie.

Good weather encouraged nighttime stargazing until the Moon rose in the small hours of the morning. Around the grounds dozens of telescopes were fixed on Pluto, M13, and whatever else the people using the telescopes felt like seeing. The Los Angeles Astronomical Society brought its 31-inch telescope, still in the testing stages on the way to full computerized tracking, for high-power views of M51, the Ring Nebula, and other time-tested favorites.

Outstanding telescopes included Paul Mahany's 18-inch f/4.6 reflector on an enormous, solid split-ring equatorial mounting built entirely from wood; Jose Sasian's 6-inch f/11 Yolo telescope with an innovative, unobstructed all-reflecting optical design; Don Adkins' beautiful 8-inch f/5.5 Dobsonian executed throughout in Honduran mahogany; the group-built 17.5-inch f/4.5 Dobsonian optimized for taking to public star parties by the Edmonton Centre of the RASC; the field-corrected 12.5-inch f/5 Schalck-Newtonian designed and built by Robert Schalck; and Peter Hirtle's finely crafted 5.4-inch f/4.5 Maksutov-Newtonian.

OBSERVERS VIEW PLUTO through Paul Mahany's 18-inch reflecting telescope at the 1989 Riverside Conference.

This year's featured Saturday evening speaker was Deborah Byrd, producer of the "Star Date" radio series and author of ASTRONOMY's Eye on the Sky column. She described how astronomical discoveries pass from the astronomer to the public through the media.

The Sunday evening RTMC Merit Award ceremony recognized accomplishments in telescope design, outstanding craftsmanship, and new ideas. Through the Eyepiece columnist Rick Shaffer, a member of the telescope award committee, bestowed his infamous "Bozo Awards." And with a huge grin and his famous yodel, conference chairman Clifford Holmes presided over the drawing for numerous door prizes.

A full report on innovative telescope design at the RTMC appears in the Summer 1989 issue of *Telescope Making* magazine.

UNIQUE PLANETARIUM OPENS IN BRITAIN

Britain's first privately owned and operated planetarium opened recently in the small town of Southend-on-Sea, some fifty miles east of London. Built in 1984 by astronomy enthusiast Harry Ford, Southend Planetarium consists of a 12-foot-diameter fiberglass dome with a seating capacity of thirty. The planetarium projector is powered by a 4-volt flashlight bulb and displays stars and deep-sky objects down to 4th magnitude.

"It is a simple planetarium," said Steve Tidey, who now owns and operates the facility. Under Tidey's directorship, the planetarium has become a popular attraction for hundreds of schoolchildren who want to learn about the sky. "A typical program lasts about forty minutes, and we normally feature material for schoolchildren between six and twelve years of age.

"We believe that by spreading knowledge through the kids," said Tidey, "we can inspire many of them to get interested in astronomy in the future. The fact that we can do it ourselves, without the aid of a large museum, amazes us every day." ☐

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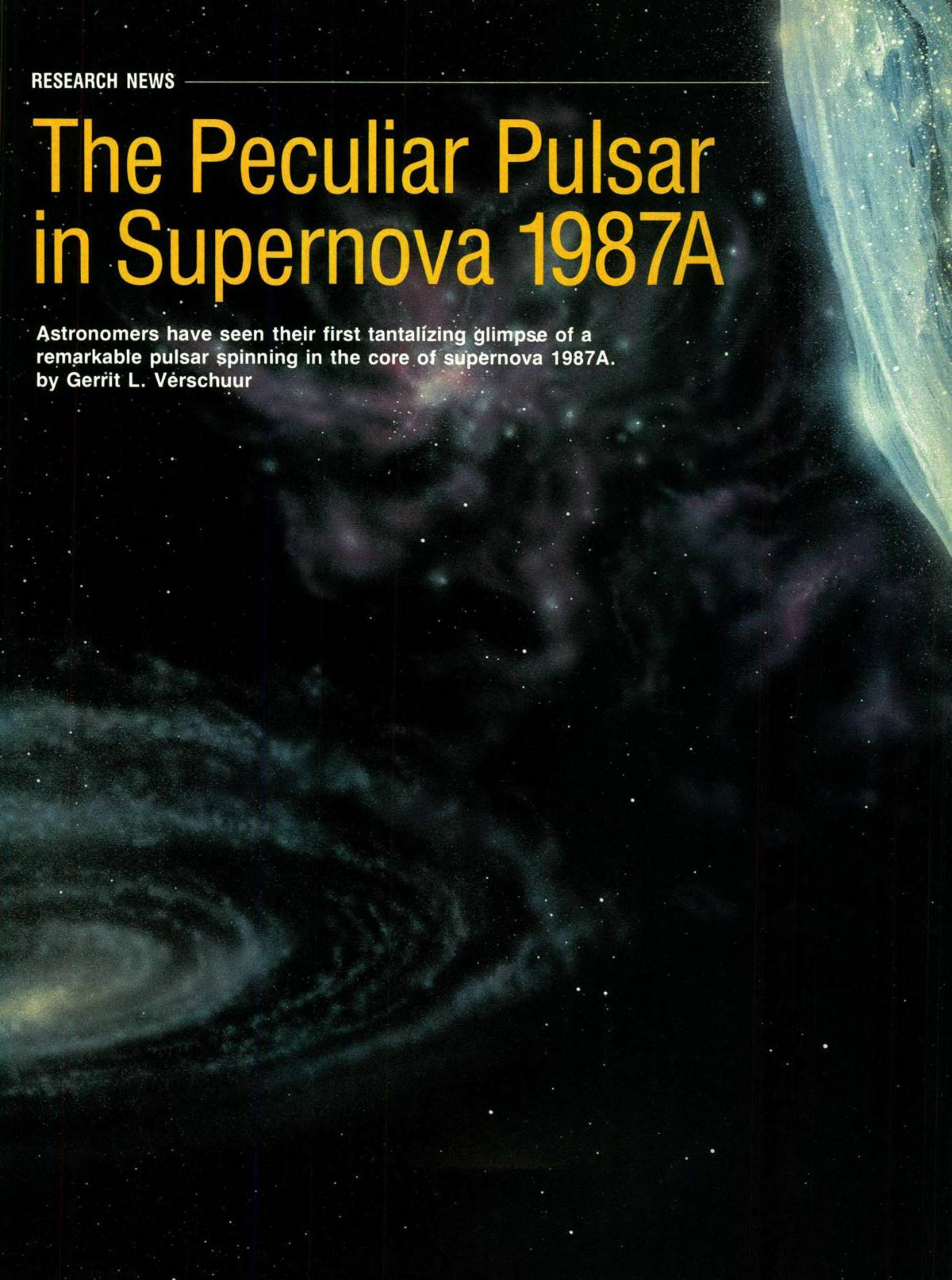
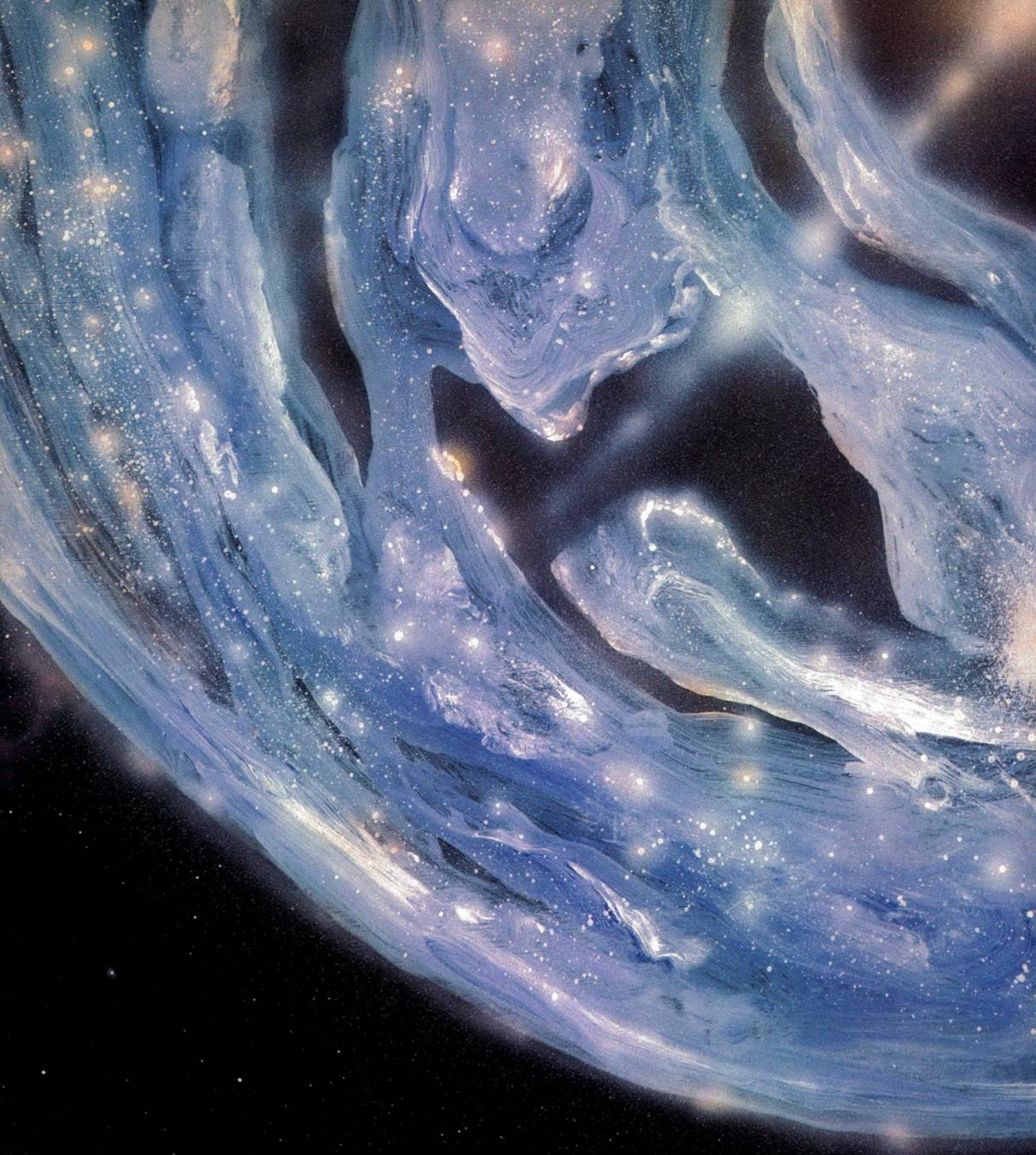
The Peculiar Pulsar in Supernova 1987A

Astronomers have seen their first tantalizing glimpse of a remarkable pulsar spinning in the core of supernova 1987A.

by Gerrit L. Verschuur





A BROKEN SHELL of incandescent gas alternately obscures and reveals the flickering light of the supernova 1987A pulsar.

On February 23, 1987, astronomer Ian Shelton stumbled upon one of the most important astronomical events of the century — the explosion of supernova 1987A in the Large Magellanic Cloud. Within days, every telescope in the Southern Hemisphere was turned toward the Milky Way's companion galaxy to observe the brightest supernova in nearly four hundred years. At long last, astronomers could use sensitive instruments to explore the intimate secrets of a supernova, and the resulting observations would subject modern theories on how supernovae are born and evolve to their first rigorous tests.

A crucial prediction of all these theories is that a supernova like 1987A should leave behind a neutron star — an incredibly dense, rapidly rotating object that forms when the core of the progenitor star collapses, the event that triggers the supernova. Although there have been several strong indications that a neutron star resides at the center of supernova 1987A (see "The First Hints of the 1987A Pulsar" on page 23), astronomers had been waiting anxiously for direct observational proof.

The wait came to an end on January 18, 1989. On that night, a team of researchers recorded a series of pulses coming from a spinning neutron star inside the supernova. But the observations revealed a star totally unlike anything ever seen before and far different from what theory had predicted. To top things off, no pulses have been seen since January 18, and no one knows if or when more pulses will make their way through the nebulosity surrounding the neutron star.

Astronomers had expected the neutron star to appear as a pulsar, broadcasting a series of regular pulses in the visible, radio, and x-ray parts of the spectrum. The pulsar's visible light pulses would arrive first because they are affected least by the incandescent nebula. Radio pulses are absorbed in the hot gas of the nebula and probably won't arrive until the expanding nebula has thinned out substantially, perhaps a decade or more from now.

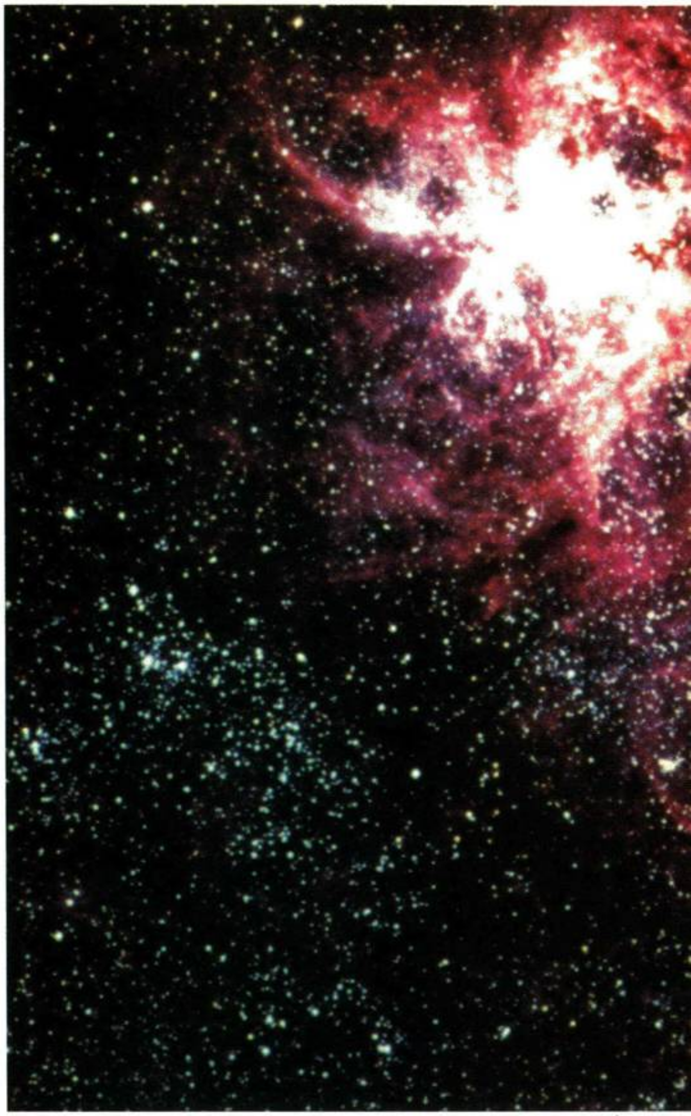
Supernova 1987A offers astronomers an unprecedented opportunity to observe a pulsar in its infancy. By watching the pulsar "turn on" and monitoring its behavior as the brightness of the supernova changes with time, astronomers hope to learn just how the neutron star and nebula interact. Theory predicts that the neutron star should have a powerful magnetic field, which, through an elegant chain of physical interactions with the surrounding nebula, converts rotational energy from the star into heat. (The heat keeps the nebula glowing long after the energy of the explosion dies away.) Astronomers very much want to witness this process.

Searching for the Pulses

On the night of January 18, 1989, Tim Sasseen, a graduate student in physics at the University of California at Berkeley, and John Middleditch, supercomputer wizard from Los Alamos National Laboratory, were observing with the 4-meter telescope at Cerro Tololo Interamerican Observatory in Chile. They were pulsar-hunting.

"This was my fifth trip," Sasseen recalled. "We hadn't seen anything yet and I was getting a little disheartened. But our level of optimism was high. Actually, every time I left to observe, my friends enthusiastically predicted positive results. That kept me going."

Still, he had reason to doubt they would find the pulsar. By then, thirty-seven separate experiments at three observatories in Chile and Australia had failed to find the hoped-for signal. Part of the problem may have been the short length of their observing runs. "We had been doing short one-hour runs because we had to share the telescope with other programs," Sasseen said. "In addition, long runs were impossible because it was very tricky to link separate data tapes together." Each magnetic tape recorded data at a rate of 5000 hertz (5,000 times each second) and quickly filled up; a very accurate clock was required to synchronize the different tapes. As Sasseen said, "Linking tapes was complicated so we did not go to multiple tapes until we were sure what we were doing."

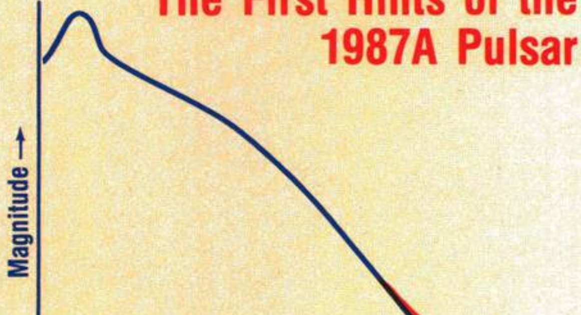


By January 18 they had solved all the problems and began a long night's observing run. In seven hours of observing they recorded over 120 million data samples, each 200 microseconds long. The tapes would later be analyzed on the supercomputers at Los Alamos to see if any pulses had been found.

Sasseen helped construct the detector they used, a silicon photodiode. "For me it was a straightforward physics experiment, which happens to measure something astronomical," he said. "The silicon detector is sensitive to the entire visible spectrum and into the near infrared. It's a very efficient device that responds to 60 percent of the photons striking it, compared to less than 10 percent for other photomultipliers." The diode is

SUPERNOVA 1987A GLOWS BRIGHTLY near the Tarantula Nebula in 1987. Two years later, the Cerro Tololo 4-meter telescope (inset) first detected the pulsar's rapid heartbeat.

The First Hints of the 1987A Pulsar



Two lines of evidence lead astronomers to think a pulsar is spinning at the center of supernova 1987A. The first evidence arrived on Earth three hours before any light from supernova 1987A, when two huge, underground detectors captured nineteen of the elusive, ghostlike particles known as neutrinos.

The neutrinos confirmed that the core of the progenitor star had collapsed. The neutrino observations also gave a strong indication that the star's collapsed core formed a neutron star. Although theorists realized twenty years ago that neutron stars form during the explosion of massive stars, this was the first direct evidence that the theories were correct.

The second piece of supporting evidence did not arrive until nearly two years after the neutrinos. Beginning approximately four months after the explosion, the light from supernova 1987A halved in brightness every 78 days. (The supernova's measured brightness is shown in red on the light curve at left.) This steady decline was just what astronomers had expected because 78 days is the half-life of the radioactive cobalt created in the debris of the explosion. The radioactive decay produces energy in the form of gamma rays that powers the nebula and keeps it shining. After about a year the decline accelerated as the nebula thinned out and more gamma rays escaped directly from the nebula without heating it.

In December 1988, however, the rate of decline in the supernova's brightness began to slow. (The blue line on the light curve represents what the brightness would have been had the decline continued apace.) This means that some source of energy is now helping power the nebula, partially offsetting the declining contribution from radioactive decay. Astronomers think the extra power source is probably a pulsar.

commercially available and is typically used for controlling room light switches. However, unlike the everyday version, this diode required special low-noise amplifiers to boost the current, which was then converted to digital form and recorded on magnetic tape.

"The light levels from the pulsar are very low," Sasseen pointed out. "The expected pulses would produce a very small signal in proportion to the light from the supernova." They were searching for the merest flicker against the brilliance of the light still emerging from the remains of the explosion.

After the observing session, Middleditch brought the tapes back to the United States and analyzed them on his Cray computer. On Sunday, January 22, he experienced the first glimmering of the pulsar. He soon realized, however, that the structure of the pulses was far more complex than he, or anyone else, had expected. His excitement was tempered by the need to probe the nature of the signal further. He had to be certain of the detection, figure out the pulsar's characteristics, and then wait for his colleagues to look at the data before they, too, became convinced of the pulsar's reality.

Sasseen's first reaction to the pulsed signal was guarded. "An earlier signal had not panned out," he recalled. "It took me about a week before all my immediate objections had been accounted for, and then I got excited."

A Most Unusual Object

The pulsar they had seen was a total surprise. The pulses from supernova 1987A repeated at a rate of 1,969 times each second, which was far faster than anyone had predicted. The research team had discovered the first *sub*-millisecond pulsar, and it was flashing three times as fast as any pulsar ever observed. Furthermore, all the other millisecond pulsars, those pulsars with a period of a few milliseconds or less, are believed to be millions of years older than the supernova 1987A pulsar. (See "On the Trail of Exotic Pulsars" by Gerrit L. Verschuur, December 1988.)

The surprisingly rapid rotation of the pulsar was only the first of several shocks that Middleditch and his colleagues had to digest. Unlike other young pulsars, the pulsar in supernova 1987A did not spin more slowly as it aged. (The youngest pulsar prior to the explosion of supernova 1987A was the pulsar in the Crab Nebula, which was born in A.D. 1054 and is the prototype for all young pulsars.) Although the rotation rates of pulsars slow down very gradually, the effect should have been apparent over seven hours of observing.

Even more perplexing, the frequency of the pulses varied cyclically with a period of about eight hours. In addition, the pulsar's brightness changed erratically by about a magnitude during the seven-hour observing session. The astronomers knew that the brightness changes could be accounted for by clouds of dust in the expanding supernova shell drifting either in front of or away from the pulsar, but the cyclical variations challenged their imaginations.

There were more surprises to come, however. When the astronomers returned to the telescope on January 31, there was no sign of the pulsar! Nor was there again on March 21, 24, 27, or April 4. What happened? Had their claim of a detection been premature? Was the signal spurious? The researchers argued that if the signal was spurious, it surely would have been seen again during a thirty-minute observation of a globular cluster that they made immediately following the supernova 1987A observation, and yet none was seen. Because the globular cluster data revealed no such signal, they were confident that all of their equipment had been operating normally.

Why, then, had the pulsar become invisible? Had it switched off, or was it hidden from view by an opaque cloud of gas and dust in the supernova shell?

Jerome Kristian refuses to speculate. Kristian, an astronomer at the Observatories of the Carnegie Institution of Washington, is the lead author of the paper that formally reported the pulsar's detection (*Nature*, March 16, 1989). "I'd like to see it again," is all he will venture. However, he does add that "there is a strong temptation to overinterpret the data."

A 'Planet' in the Supernova?

This tendency was evidenced by a flurry of publications that appeared even before the ink on the IAU telegram had time to dry. Astronomers quickly offered suggestions as to why the pulsar showed a cyclical change in period. One possibility is that the phenom-

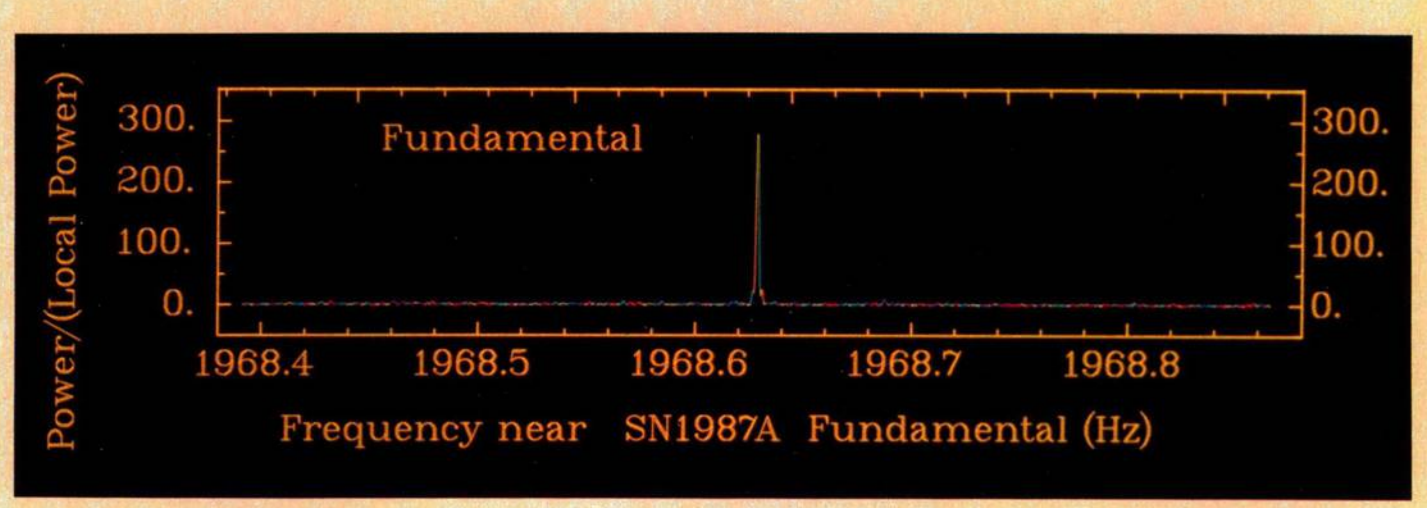
Measuring the Pulsar's Pulse

Teasing the pulsar's weak signal out of the much brighter glow of supernova 1987A is a task that can be handled only by the largest and fastest computers in the world. The computer uses the brightness of the supernova, recorded by a detector on the telescope, as data. Hidden in this data, perhaps as much as 6 to 7 magnitudes fainter than the supernova, lies a string of pulses. The supercomputer searches the data within particular frequency (pulse-rate) intervals by a process called Fourier analysis, which determines whether any one interval contains more power than the others. If only random noise is present, then the energy in all the frequency intervals should be of equal strength.

One way to envision the process is to imagine yourself at the beach listening to the soothing roar of waves breaking on the shore. You hear the sound surge, fade away, and then surge again. The surge rate would be equivalent to the pulsar's frequency. The sound of individual breaking waves produces "white" noise — a mixture of purely random sounds — and is equivalent to the background noise emanating from the much brighter supernova.

If you made an hour-long recording of the sounds of the waves and performed a Fourier analysis in a computer, it might show you that many of the higher frequencies present in the actual sound of the breaking waves were present in equal proportion. It may also show that there was extra energy present at, say, 6 cycles per minute, the frequency of the arriving waves that you observed at the beach.

Although you could measure this frequency by simply timing the arrival of the waves with the second hand of your watch, a computer Fourier analysis makes use of a convenient trick. Instead of analyzing the data in time intervals, it converts the hour's worth of data into frequency intervals, a process known as a Fourier transform. The reason for doing this is that it is far easier to



write computer programs to explore the data in frequency than to analyze the data as a function of time. Thus, a Fourier analysis of our hour's worth of data would show an excess signal around 6 cycles per minute and show that there is no other excess signal in the data up to the highest frequency to which the ear is sensitive, roughly 10,000 hertz.

The light waves emerging from the supernova should produce a "white-noise" frequency spectrum when they are detected at the telescope. That is, all frequencies should be equally represented within the limits of the particular detector, which is designed to respond to a wide range of frequencies, including that of the expected pulsar. Middleditch's supercomputer performs a Fourier analysis on the 120 million samples of the light from supernova 1987A to determine whether any frequency is represented more than any other. If so, this is likely to be the signature of the pulsar.

The search for very weak pulses from supernova 1987A is made more complex because the rate at which pulses arrive at the telescope is affected by Earth's rotation and motion around the Sun. (These motions produce a Doppler shift that affects the observed pulse frequency.) In addition, the pulsar may be slowing down as the neutron star loses energy. Therefore, the computer searches for a pulse beat that also changes with time. Add in the possibility that the pulse period is cycling back and forth in some manner, because of the influence of some orbiting object, for example, and it becomes clear why only the most powerful computers can perform the Fourier analysis.

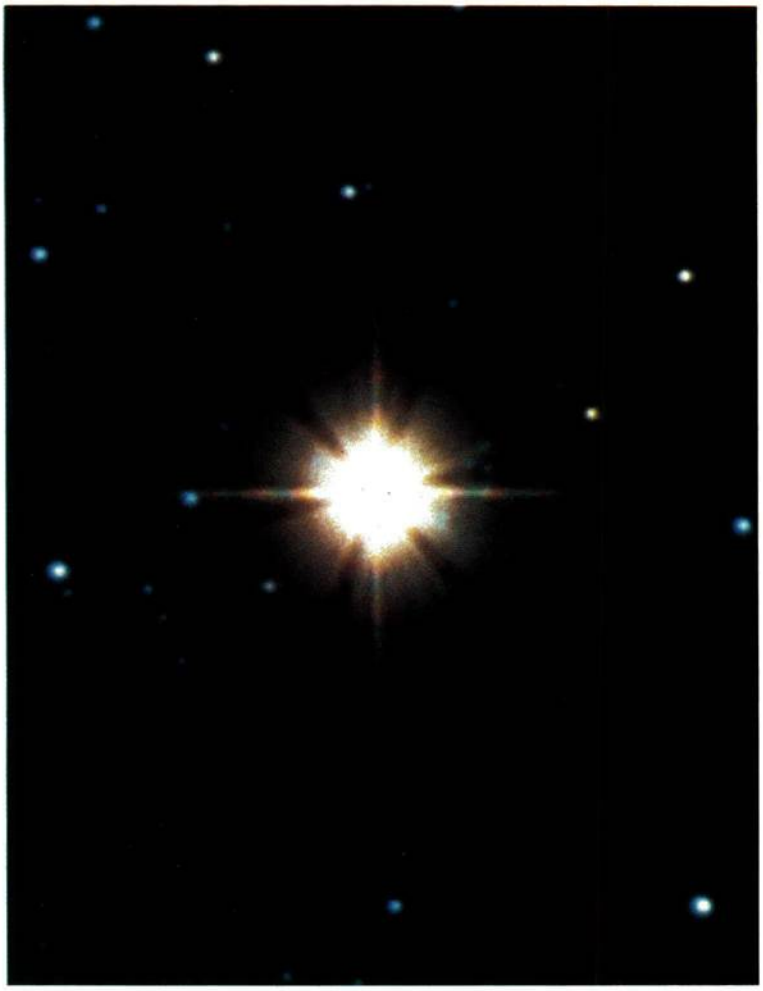
In essence, the search for a repeating signal in a long data set is simple, provided the signal is always present and does not change from moment to moment. In practice, when the signal is well below the noise created by the detector or the random nature of the light from the supernova and is varying due to the unpredictable vagaries of the pulsar, the task is extremely complex. ☐

enon is caused by an object with the mass of Jupiter orbiting about 1 million kilometers from the neutron star. At this distance the object would have lain well inside the original blue supergiant; thus it was certainly no ordinary planet. Another possibility is that the mystery object is a solid hunk of iron formed in the supernova explosion that has subsequently gone into orbit around the neutron star. In any case, such speculations cannot be tested until the pulsar reappears and is explored further.

But the key issue remains: Was the pulsar signal real? Middleditch reanalyzed the data and was able to derive a more accurate orbit for the enigmatic object responsible for the murmur in the beat of the pulsar. He admits that before he completed the reanalysis, he wasn't sleeping too well. The more careful analysis showed that the pulse rate was changing in a manner consistent with something moving around the pulsar in an elliptical orbit with a 7.11-hour period. This finding greatly relieved Middleditch because he couldn't imagine a systematic effect in either the optics or computer programs that would be so cruel as to simulate an elliptical orbit.

After Middleditch subtracted this modulation from the data, he found that a small wobble in frequency still remained. This hinted at the presence of yet another object, one orbiting the neutron star at a distance of about 600,000 kilometers every 1.9 hours. "Only the most pessimistic would now say that we have not seen the pulsar," said Middleditch, by now well rested. He remains unsure whether orbiting bodies or some peculiar distortions in the shape of the neutron star are necessary to account for the phenomenon. As Kristian cautioned, it is probably premature to speculate much further until the pulsar is observed again.

What about the fact that the pulsar was rotating so quickly? Five astrophysicists from Columbia University, led by Qingde Wang, suggested that the pulses were not due to rotation at all. Instead, they believe the neutron star may be ringing like a bell. In this scenario, the material left over after the collapse of the blue supergiant's core would have crashed onto the newly born neutron



AS SUPERNOVA 1987A FADES and the opaque clouds of gas and dust surrounding it thin out, astronomers hope to observe the mysterious pulsar once again.

star's surface and given the neutron star a blow like a hammer striking a gong. This hypothesis could also explain why the pulsar's rotation rate isn't slowing down: the neutron star is still vibrating from the collision and the real pulsar hasn't even been seen yet.

The discoverers disagreed with this interpretation, however. "The harmonics we found in the data rule out a ringing effect," said Middleditch. "The pulses have to be due to rotation."

Nevertheless, such an extremely rapid rotation rate is totally unexpected for a newly born pulsar. Other millisecond pulsars are millions of years old, rejuvenated into spinning rapidly by matter spilled onto them from binary-star companions that have evolved to the red giant phase. This problem led Stan Woosley of Lick Observatory and Roger Chevalier of the University of Virginia to look again at the theory of neutron-star formation. They suggested that within a day of the supernova explosion, some of the ejecta may have fallen back onto the neutron star, which was rotating normally at the time, and caused it to spin faster. Unlike normal supernovae, which blast apart red supergiant stars, the blue supergiant that exploded to form supernova 1987A had a high enough density near its core to allow such a process to occur.

A group of physicists from the University of Illinois, led by M. A. Alpar, examined the implications of a sub-millisecond pulsar in supernova 1987A. Writing in *Nature* (March 23, 1989), they said that the pulsar "challenges almost all the main features of current theories of neutron-star formation, structure, and evolution." In other words, if this pulsar is confirmed, virtually all previous pulsar theories are in grave trouble. Even more fundamentally, they added, the sub-millisecond pulsar challenges current models governing nuclear interactions and the behavior of matter at the highest densities. They confessed that it would be a pity if the pulsar were not confirmed, because it was exciting to think about the ramifications of the peculiar observations.

The Curtain Remains Closed

Why hasn't the pulsar been seen again? Middleditch said that "the reason it is not coming back is really telling us something, although we don't yet know what. It could be accretion that has destroyed the pulsar emission mechanism, or something may be blocking the view."

If dust in the surrounding nebula is hiding the pulsar from our view, it should become visible again when it manages to shine through another hole in the dust. In preparation for that moment, the team is now making more frequent observations. They observe the supernova for about an hour every three nights at Cerro Tololo and for a couple of hours each week at Siding Spring Observatory in Australia. The data tapes are hurried to Los Alamos where Middleditch sits at his computer terminal and manipulates 67-million-point databases at the touch of a key. "The average experimenter can handle about 1 million points in these calculations," he said, but that is not enough to find elusive sub-millisecond pulsars.

Kristian, Middleditch, Sasseen, and their colleagues want a real-time data link so that they can observe the pulsar at the beginning of every evening, analyze the data, and then, if the pulsar appears, immediately preempt the telescope for the rest of the night to continue observing. That way, if the pulsar disappears from view again before they return to the telescope a few nights later, they still have a full night's worth of data. They also plan to use a germanium detector that is sensitive to infrared wavelengths at 2 microns where the dust around the supernova may be more transparent. "The background signal from the supernova is less in the infrared," Sasseen pointed out. "The supernova shell is brightest at visible wavelengths, which makes the pulsar harder to see against the shell's glare." The group expects to install the equipment this summer.

Middleditch is very optimistic. "When we begin to observe with the germanium photodiode we should see the pulsar right away," he predicted with confidence.

There is a widespread feeling among astronomers that the pulsar will reappear in the very near future. Yet no one is willing to predict just when. As Jerome Kristian said, "We just want to observe it again." Only then will the case of the missing pulsar be solved. ☐

Gerrit L. Verschuur is a freelance science writer and radio astronomer who lives in Bowie, Maryland. His book Interstellar Matters *was recently published by Springer-Verlag. Verschuur's article "The Day the Sun Cut Loose" appeared in last month's ASTRONOMY.*

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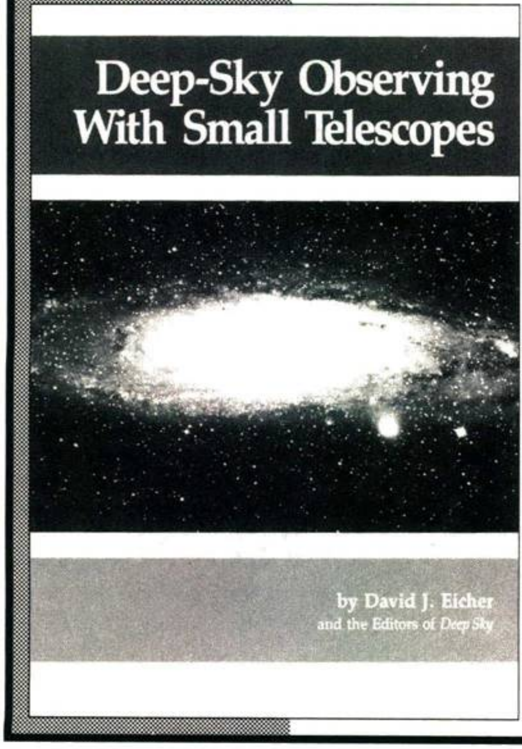

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NEW VIEWS OF MARS AND PHOBOS

The Soviet Union's short-lived *Phobos* mission has given scientists their first close-up look at Mars in seven years.

by Robert Burnham

When the *Phobos 2* spacecraft went out of control in Mars orbit on March 27, 1989, one of the most ambitious and scientifically valuable planetary missions ever launched by the Soviet Union came to a premature end.

The *Phobos* mission consisted of placing two spacecraft in Martian orbit to conduct a wide-ranging program of experiments on Mars and its moon Phobos. The mission's central focus was landing two instrument probes on Phobos and making a breathtaking cruise at 150-feet altitude over its cratered surface. Both spacecraft were launched in July 1988, but *Phobos 1* was lost through human error six weeks into the flight. *Phobos 2*, whose payload was almost a twin of *Phobos 1*, arrived at Mars in late January of this year.

Despite *Phobos 2*'s early demise, which came before the craft had made its dramatic flyby, the mission was in no sense a total loss. Besides performing experiments during the outbound cruise, *Phobos 2* had spent two months in Mars orbit collecting unique and significant data before it failed. After even a preliminary look, scientists have already seen new findings.

THE ONLY TOWN IN THE GAME, Moscow offered planetary scientists a mission to Mars earlier this year.

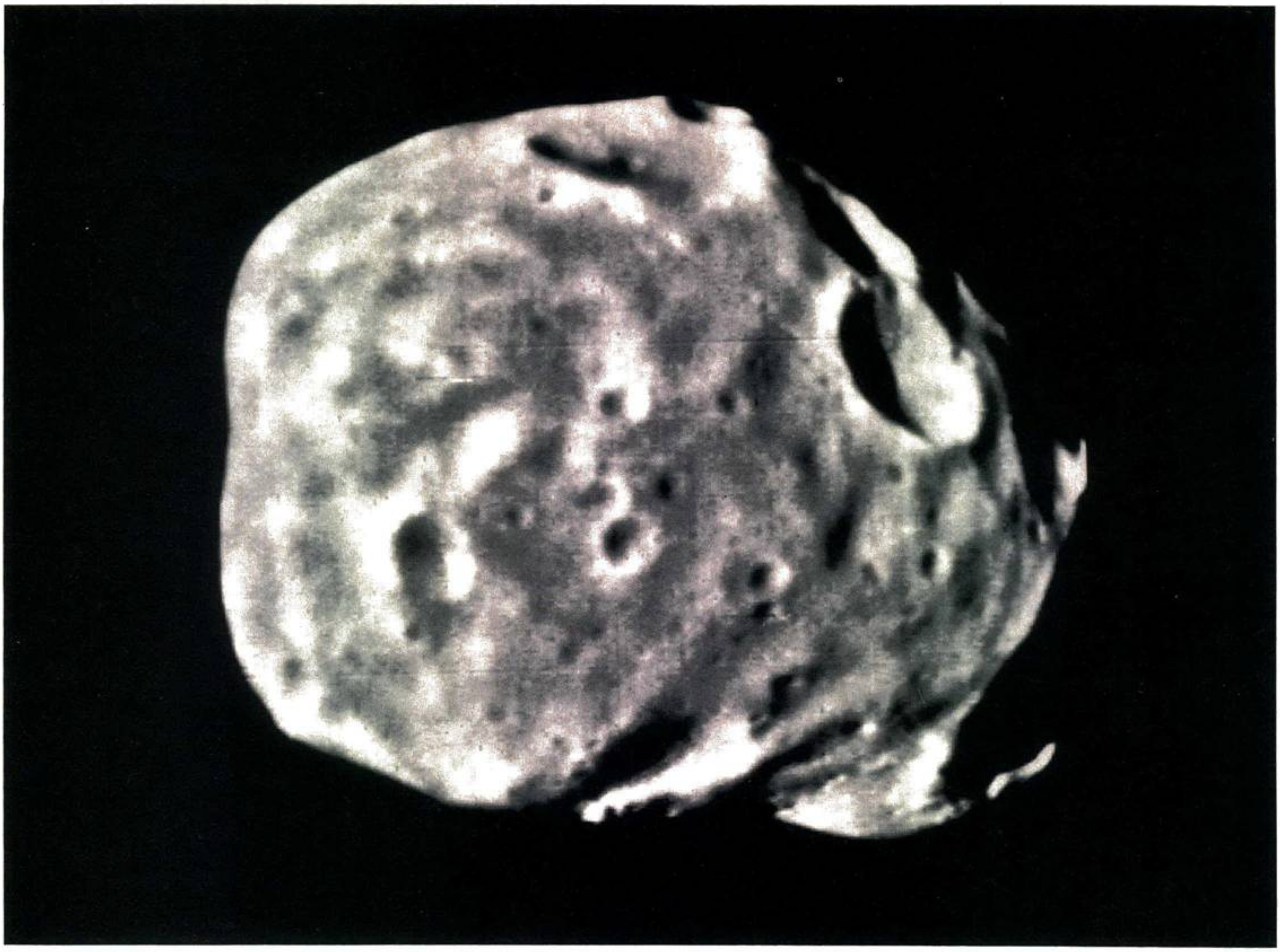
Because the mission ended before the close encounter with Phobos, most of the mission's results have come from the instruments that began work upon arrival at Mars. For the most part, these instruments functioned in the infrared and visible parts of the spectrum or sensed particles and fields in Mars' vicinity.

Planetary scientist Bruce Murray of Caltech was one of a number of U.S. researchers, along with many other foreign scientists, that the Soviets invited to participate in the mission, either as experimenters or support scientists. He explains that four experiments yielded especially important results: ISM, a spectrometer; KRFM, a 10-band filtered photometer and radiometer (heat sensor); TERMOSKAN, a scanning radiometer; and AUGUST, a spectrometer that used infrared, ultraviolet, and visible radiation. The first three instruments examined Mars' equatorial region from west of Olympus Mons to east of Valles Marineris; the last probed the Martian atmosphere as the spacecraft passed on to the night side and the planet's limb occulted the Sun.

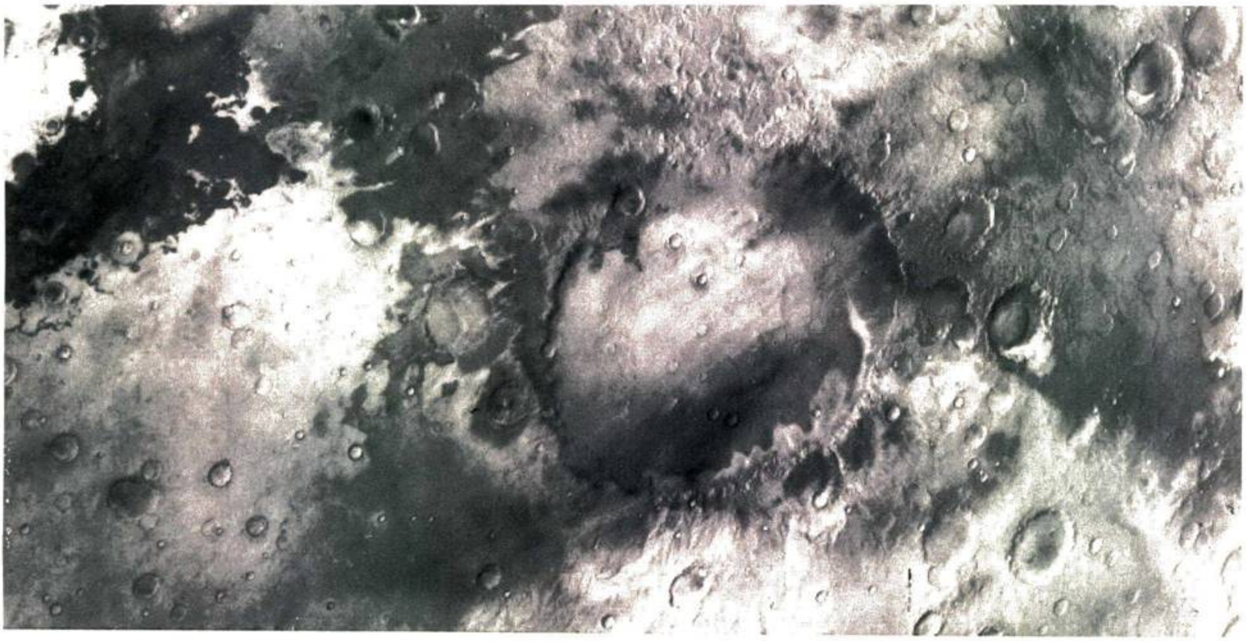
According to Conway Leovy of the University of Washington, AUGUST and KRFM observed dust and water ice in the atmosphere. KRFM measured the size of the particles over the Tharsis volcanos, Arsia Mons in particular. Working in the ultraviolet part of the spectrum, AUGUST detailed the atmospheric layers more clearly and measured the size of dust particles at an altitude of about forty miles. The infrared part of the AUGUST experiment showed water vapor features at three distinct levels in the atmosphere, which may indicate large and important variations in temperature.

TERMOSKAN mapped the temperature of the Martian surface. Many of its images, Murray observes, show that the outflow channels, which are former water courses, and the "chaotic terrain," in which the channels originate, are distinctly cooler than the surrounding higher ground. (See photos at right and overleaf.) In a related experiment, KRFM found many places where the surface rocks and dust responded to heating and cooling in specific ways that will help scientists determine their composition and average particle size.

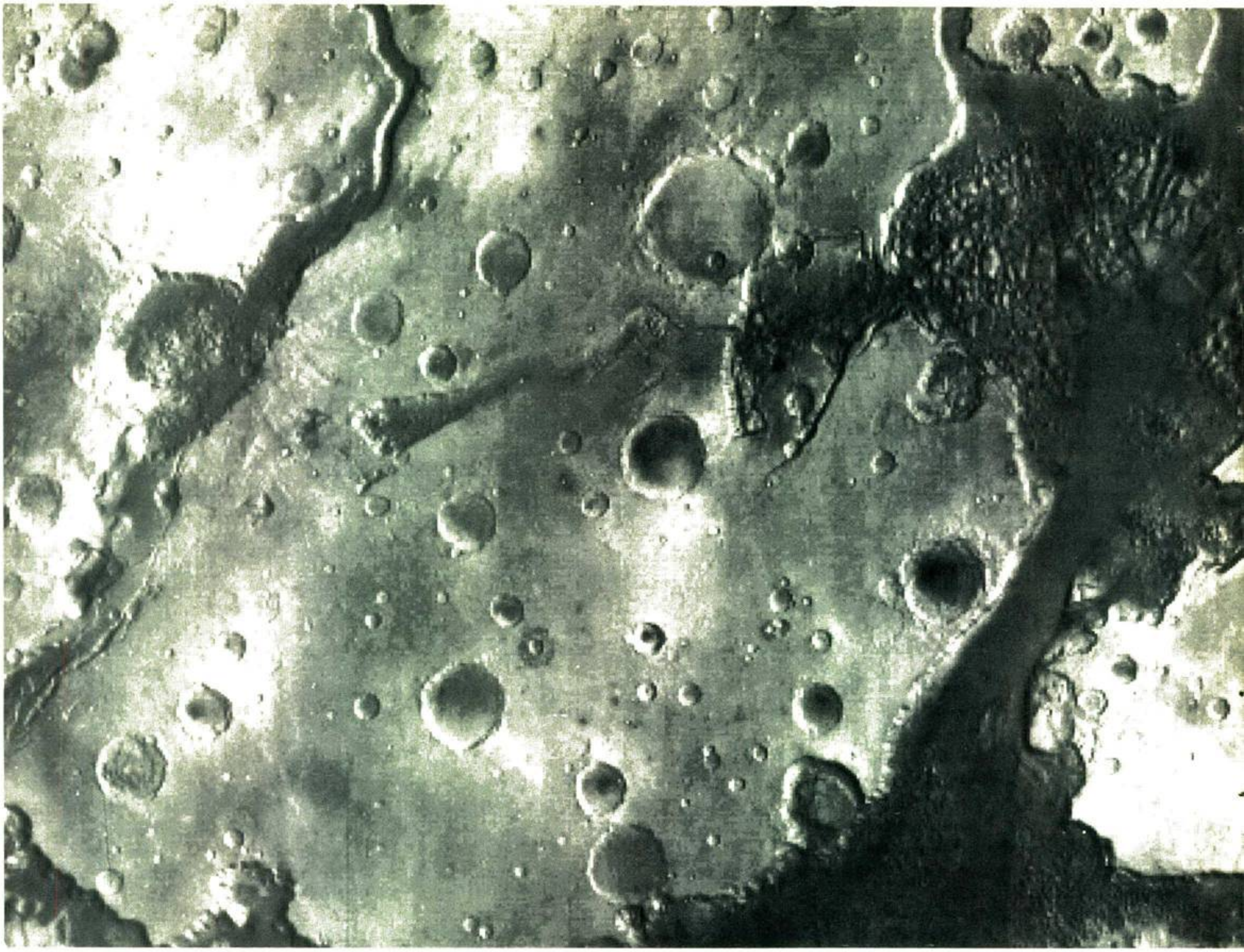
ISM's spectrometric measurements let researchers determine the amount of carbon dioxide gas above Pavonis Mons, a lofty volcano in Tharsis. Because scientists know how much carbon dioxide exists in the atmosphere, they can compare the amount seen over the volcano with the amounts down to Martian "sea level" and thereby determine the volcano's altitude. This



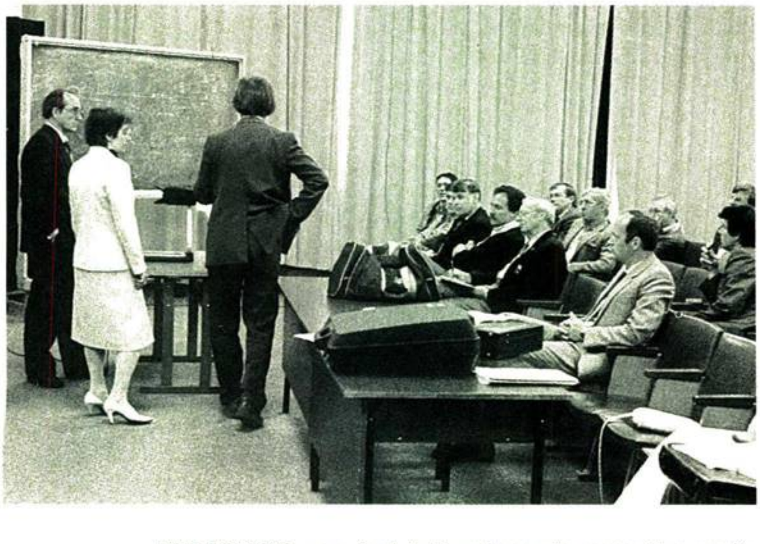
MARS' MOON PHOBOS was photographed by *Phobos 2*'s television camera from a distance of 270 miles. Photos through red and blue filters revealed a surface almost uniformly gray, suggesting a homogeneous surface mineralogy.



SEEKING WARMTH from the Martian surface, the TERMOSKAN radiometer took infrared pictures showing cool (dark) and warm (light) areas. In the center is the 300-mile-diameter crater-basin Schiaparelli near Sinus Meridiani.



CHAOTIC TERRAIN and water-carved outflow channels both appear dark (and hence are cooler than their surroundings) in this TERMOSKAN image of the Capri Chasma region at the eastern end of Valles Marineris.



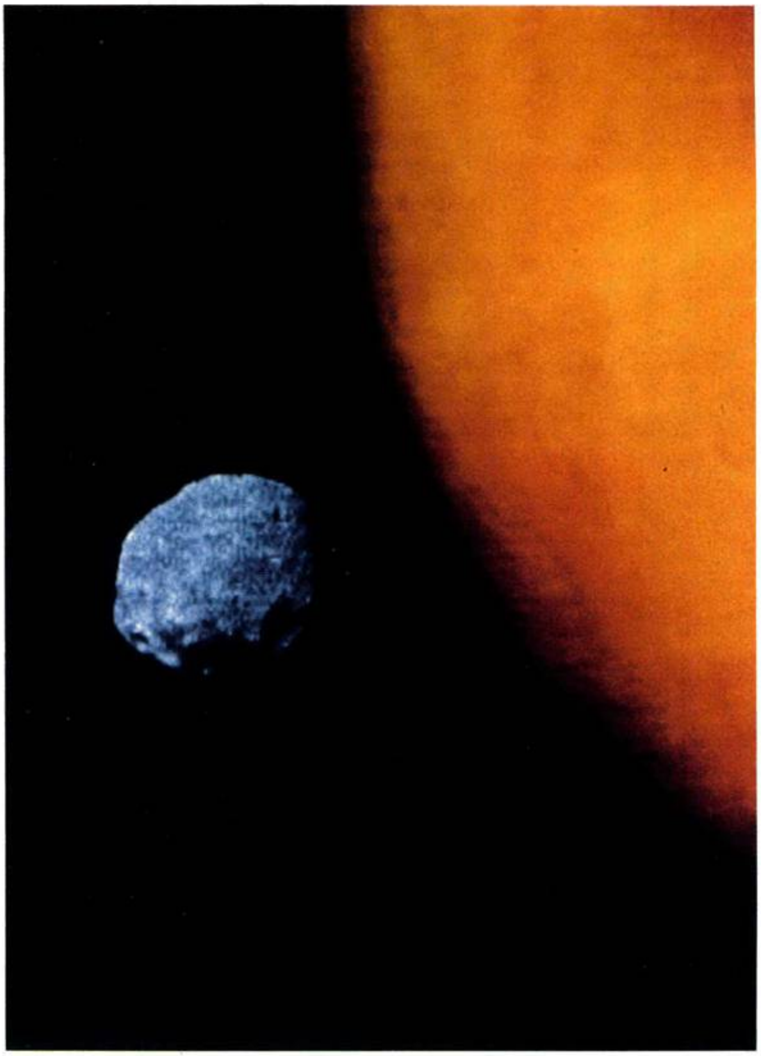
THE SOVIETS were forthright and open in presenting results from *Phobos* — and in discussing why the spacecraft failed.

method of measurement revealed the summit caldera was almost 6 kilometers deep, a new finding. ISM also showed that throughout the Tharsis area, surface materials have more water bound into their chemical structure as one goes east toward Valles Marineris.

Another goal of ISM and KRFM was to map probable rock types on the surfaces of Mars and Phobos at infrared wavelengths, where minerals have distinctive spectral features. When the data are calibrated, scientists hope to "color in" *Viking* images with *Phobos*-derived rock types. "There's clearly something interesting going on there," says Dale Cruikshank of NASA's Ames Research Center, "though we'll have to wait for the calibrations before we can pinpoint what the variations mean."

Larry Esposito of the University of Colorado noted that the surface materials on Phobos that have been warmed by sunlight vary in how long they hold heat when the moon's rotation carries them to the night side. Because exposed bedrock tends to warm up and cool off more slowly than dust, differences in heating and cooling rates should help researchers map where the dusty surface layer lies thick or thin.

ISM revealed that the minerals on the surface of Phobos are extremely dry, with even less water bound into their structure than ground-based measurements had



POTATO-SHAPED PHOBOS is darker and mineralogically different from the tawny deserts 6,000 miles below.

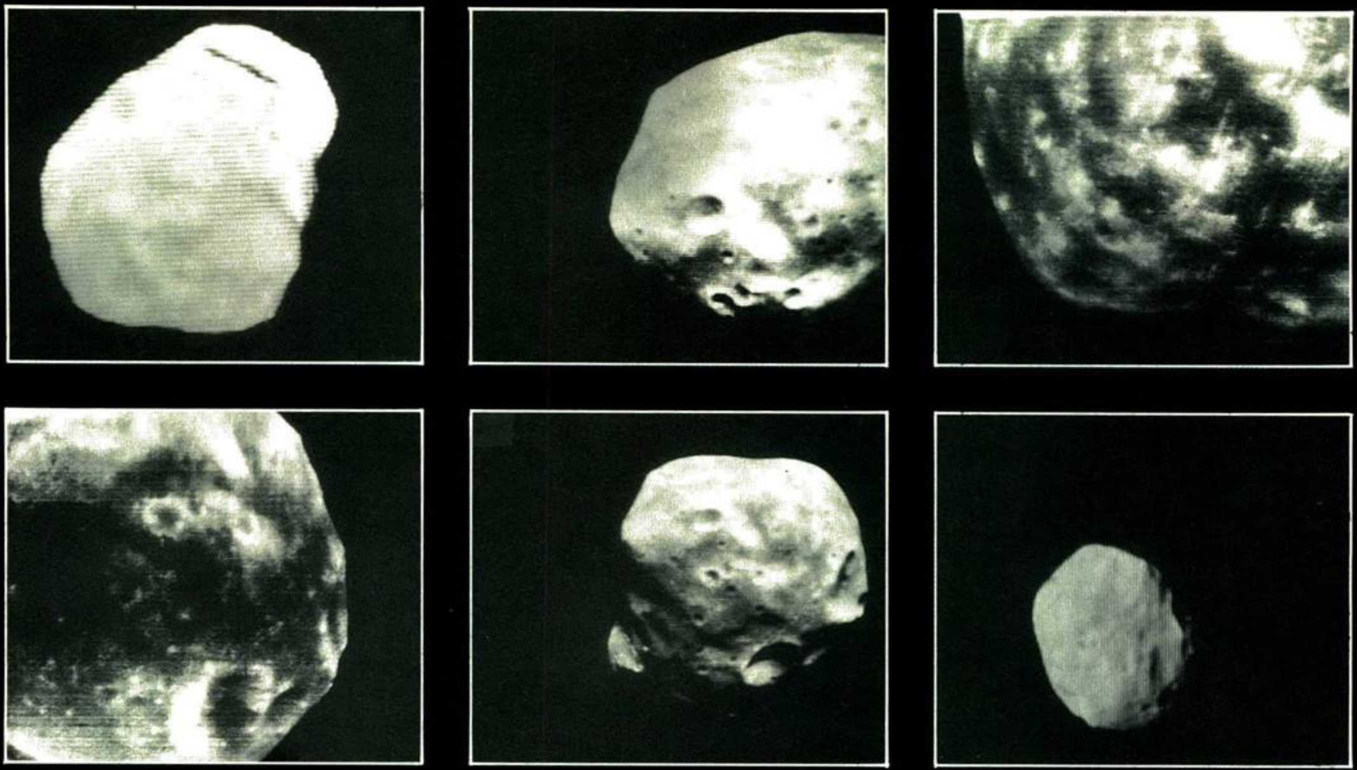
suggested. This implies that Phobos is probably not a carbonaceous chondrite type of asteroid and it may cause difficulties for Mars-exploration scenarios that envision using Phobos as a place where water is readily available for conversion into hydrogen fuel. The finding, however, does not rule out the possibility that water may still exist deeper in the moon's interior.

The *Phobos* payload also included instruments working in the visible part of the spectrum. The FREGAT experiment used CCD cameras that focused mainly on Phobos, providing blue- and red-light images at low resolution and white-light images at high resolution. FREGAT took about forty pictures, all but eight showing Phobos alone. (The eight showed Phobos silhouetted against Mars, which provided a useful calibration of the moon's brightness.) FREGAT imaged parts of Phobos that *Viking* missed, and preliminary red-to-blue image comparisons show that Phobos is almost uniformly gray.

In another experiment, scientists carefully tracked the spacecraft's motions by means of Doppler shifts in its signals. This will let them more precisely define Phobos' orbit around Mars, which is slowly decaying. Phobos circles Mars three times per Martian day, so it is always speeding ahead of the small tidal bulge it raises in the surface rocks of the planet. Because the bulge lags behind the moon, it pulls on Phobos, retarding the moon slightly and making it spiral slowly inward. Eventually, Phobos will drop out of orbit and break up due to tidal forces from Mars. From the spacecraft's radio tracking data and the FREGAT images (which locate the spacecraft relative to the moon), scientists expect to better understand how Phobos' orbit is decaying.

Phobos' motions can aid studies of the moon's internal structure as well, says Robert Preston of the Jet Propulsion Laboratory. "We didn't get to drop the radio beacons on the moon," he notes. "But we're examining the tracking data to see what it can tell us. For example, we hope that by the time we're finished, we can model the distribution of mass in Phobos' interior and get a better mean density." This would help answer questions about the origin of the moon.

Phobos also carried instruments onboard to explore the nature of Martian particles and fields. The problem of a Martian magnetic field — its existence and size — has perplexed planetary scientists for two decades. Only four Mars flights before *Phobos* carried magnetometers; and their results showed that if the planet has a magnetic field at all, it must be very weak and lie close to the planet. "We had hoped that *Phobos 2*, with its intended 300-mile-high orbital low point, would resolve the matter," says Norman Ness of the University of Delaware. "But the spacecraft engineers put it into a



A CHUNKY ROCK measuring 11 by 14 miles, Phobos is widely thought by planetary scientists to be an asteroid captured by Mars. Therefore, it holds great interest both by itself and in its relationship to Mars.

526-mile orbit that was too high to settle the question."

He notes, however, that magnetic field and plasma experiments found a turbulent magnetic tail extending, cometlike, away from the Sun behind the planet. And the atmosphere appeared to be losing geologically significant amounts of ionized oxygen into the tail. Ness cautions that at present the observations can't discriminate between a small global magnetic field or one induced by the electrical flow of the solar wind. "We may also be seeing a more complex kind of solar wind/magnetosphere interaction at Mars than we are used to seeing," Ness remarks. "The only other nonmagnetized planet we've found is Venus, and the differences between it and Mars are too great for easy comparisons."

One vital set of results was gathered even before *Phobos 2* arrived at Mars. On the seven-month cruise from Earth, *Phobos* turned its active-cavity radiometer on the Sun and took the longest run of data yet collected that shows solar surface oscillations. This long, uninterrupted series of observations will help solar astronomers using helioseismology study the Sun's structure (see "Looking Inside the Sun," March 1989).

What, finally, went wrong with *Phobos 2*? Thomas Duxbury of JPL was in the control room when the craft lost contact with Earth and participated in the postmortem on the mission held by the Soviets. While a definitive cause hasn't yet been pinpointed, Duxbury feels it was a combination of things. "The craft, which was the first of a new design, lost one of its power supplies on the way to Mars," he says. "This left it with a 50-watt power shortage. Engineers dealt with the problem by turning off the high-gain radio link to Earth and letting the on-board computers control the craft while it was collecting data."

Yet the computers themselves were not totally reliable, he notes, and the craft had not been provided with an "auto-boot" program to orient and restart itself should it lose touch with Earth. The computers probably failed and the craft began to tumble, which made it depend totally on its batteries. But the batteries had a lifetime of only ten hours and when the ground could not reassert control within this period, the mission was lost.

No matter how abbreviated its flight, *Phobos 2* still returned the first fresh data from Mars since *Viking 1*'s lander shut down in 1982, and planetary scientists are understandably pleased. Next, it will be the turn of the U.S. *Mars Observer* craft, scheduled for launch in autumn 1992. *Mars Observer* will survey Mars from polar orbit for at least one Martian year (23 months).

And the Soviets? They will be analyzing the lessons of *Phobos* and applying them to their next mission to the Red Planet, called *Mars '94* and currently scheduled for a liftoff that year.

Continuing the international collaboration exemplified by the *Phobos* mission, a French-Soviet balloon experiment that is part of *Mars '94*'s payload will have its data relayed to Earth by *Mars Observer*. And in turn, *Mars '94* will carry an infrared mapping spectrometer that is descended from an instrument deleted from *Mars Observer* due to budget constraints.

The *Phobos* mission has ended, *Mars Observer* and *Mars '94* lie ahead. At long last, after a deep and dispiriting "data drought," Martian studies are budding with new life once again. ☐

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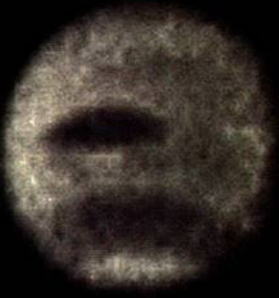
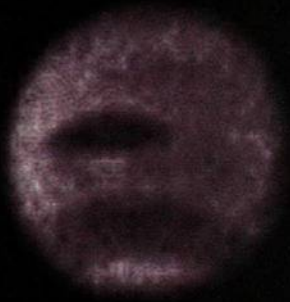
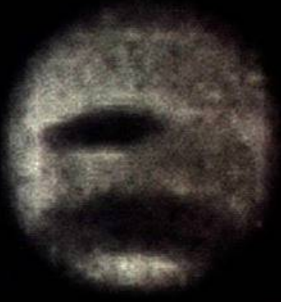


VIOLET LIGHT

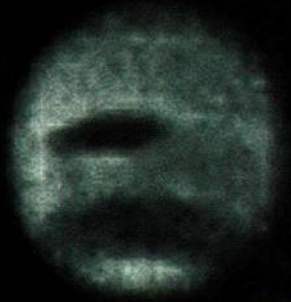
The large, dark oval at 30 degrees south latitude has a slightly brighter center in violet light. A thin, bright band appears at the boundary between the dark southern belt and the light temperate belt.

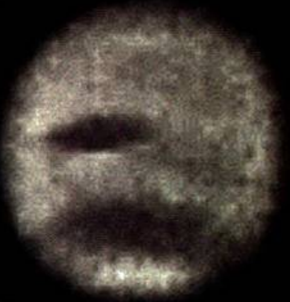




BLUE LIGHT

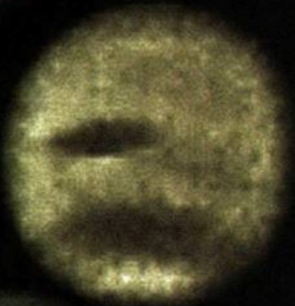
The dark southern oval, bright polar hood, and dark southern bands are the principal features in blue light. The center of the dark oval appears darker than its edges, and a small bright region is faintly visible just south of the dark feature.

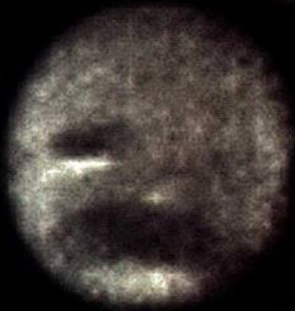




"WHITE" LIGHT

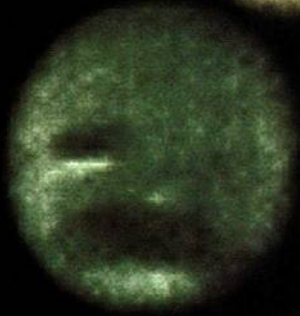
In the combined light of all colors, the dark oval feature is about 10 percent darker than its surroundings. Computer processing pulls faint detail from the "raw" images sent to Earth by the *Voyager* cameras.

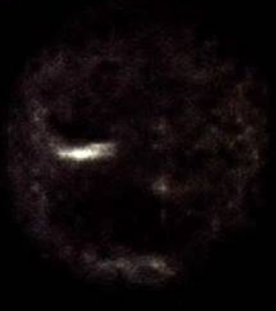




GREEN LIGHT

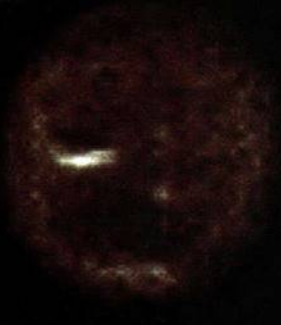
In green, the dark feature appears less distinct and smaller than it does in blue or violet light, and the light feature just south of it appears brighter. A small, bright feature appears below the center of the disk.





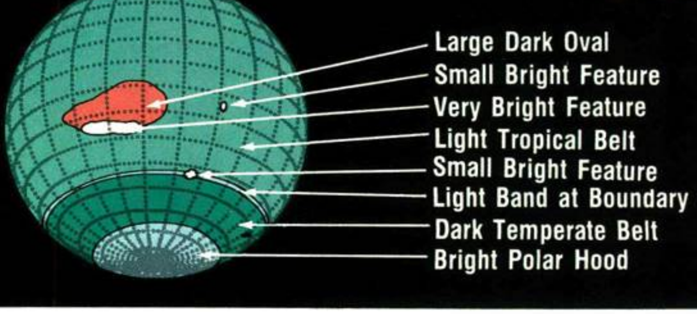
ORANGE LIGHT

A high-contrast bright feature dominates Neptune's disk, made relatively dark at this wavelength by the absorption of light by methane gas. The dark oval feature appears reduced in size. Two small bright spots may be small versions of the large white feature.



NEPTUNE GLOBE

At the time these pictures were taken, *Voyager* viewed Neptune from 26 degrees south of the Neptunian equator. The disk of Neptune appears slightly gibbous with the terminator on the right side. Neptune rotates from left to right in these pictures.


Large Dark Oval
Small Bright Feature
Very Bright Feature
Light Tropical Belt
Small Bright Feature
Light Band at Boundary
Dark Temperate Belt
Bright Polar Hood

The Colors of Neptune

With its powerful telephoto cameras, *Voyager 2* photographed several distinct features in the Neptunian atmosphere.

by Richard Berry

Neptune is a delight compared to Uranus, according to planetary astronomers and members of the *Voyager* spacecraft imaging team. A set of five images recently released by the Jet Propulsion Laboratory in Pasadena, California, shows large dark and light features, dark belts and bright cloud bands, and hints of smaller-scale atmospheric structure. The pictures were taken on May 24, thirteen weeks before the Neptune encounter.

As *Voyager* imaging team member Richard Terrile said, "We're all very excited. At Uranus we had to dig and dig to see anything even on the very best images. These images were taken three months before the encounter and Neptune already shows a lot of structure."

"The feature in the images that's so bright in orange light is probably the kind of thing we've been looking at from the ground," said Heidi Hammel, planetary astronomer at JPL. Hammel has observed bright clouds on Neptune from Mauna Kea at red and infrared wavelengths since 1986 (see "Approaching Neptune," August 1989).

"We're not sure whether it's the same feature we observed," said Hammel, "but we think it's the same type. We also think those two little bright spots on the orange frame are a similar kind of feature." These clouds appear bright because they are high-altitude clouds and therefore above much of the methane that absorbs light at the long-wavelength end of the spectrum.

The most prominent feature on the planet is the large, dark oval at 30 degrees south latitude. Its apparent shape changes dramatically with wavelength. The feature appears as a large oval with a slightly lighter center in violet light, and as a small streak with a lower contrast and a different orientation in green and orange light.

Because of its gross color properties and size relative to Neptune, the dark oval resembles the Great Red Spot of Jupiter. If anything, in fact, the dark oval is a little bigger relative to Neptune than the Red Spot is to Jupiter. "The Red Spot analogy is very tempting," cautioned Terrile, "but it's too early to guess. By the time ASTRONOMY's readers read my comments, we'll probably know a lot more about it."

"There was never any hint of things like the dark feature in ground-based images," said Hammel, "but then no one ever looked for them." She explained that observers concentrated their efforts in the red and near-infrared portions of the spectrum. Hammel, who has observed Neptune regularly for the past three years, plans to obtain images in yellow light on her next observing run at Mauna Kea to see if such features can be detected from the ground.

In these images, the dark oval and the bright feature appear side by side, perhaps even overlapping. However, it is not clear to astronomers whether the dark oval and the white feature are related or not. Hammel noted that astronomers intend to keep a close watch on the two features to see whether one is simply passing the other or if they remain together.

On the large scale, Neptune appears to have light tropical belts, dark temperate belts, and a bright polar hood in the southern hemisphere. Because *Voyager* viewed the planet from 26 degrees south of Neptune's equator at the time the pictures were taken, little of the northern hemisphere can be seen. However, *Voyager* will fly over the northern pole of Neptune during the encounter.

Astronomers are watching several small bright features with interest. These features, located near the transition zone between the light and dark belts, appear and disappear very rapidly. "It's frustrating," said Hammel, "because you see them on one rotation but not on the next. They come and go in less than eighteen hours." Said Terrile, "As we get closer to Neptune, these features will begin to be resolved. It's still a bit too early to guess about their nature."

Terrile explained that pictures taken six weeks after these images would have twice their resolution. In the following three weeks, the resolution would double again, and it would double yet again in the week-and-a-half that followed. "That's what you get in a flyby," he said, "for a long time not much happens, then what you see increases very rapidly."

As *Voyager* draws closer to Neptune, discoveries will come faster and faster. Atmospheric structure is only one area that *Voyager*'s cameras will investigate. Planetary astronomers expect *Voyager* to find several new satellites orbiting Neptune as much as a month before the August 25 encounter and to record ring arcs during the first or second week of August (see "Running Rings Around Neptune," May 1989).

Just hours after its encounter with Neptune, *Voyager* will swing past Neptune's largest satellite Triton. This small ice-and-rock body has an atmosphere, and it may be cratered, endowed with liquid nitrogen lakes, or partly frost-covered and icy (see "Searching for the 'Real' Triton," February 1989).

As of late June, reported Charles Kohlhase of JPL, the spacecraft was healthy, functioning properly, and doing regular observations of Neptune in its "observatory mode."

"Neptune's going to be nice to us," said Terrile. "The message in these pictures is that Neptune is far more exciting than Uranus. We're going to see a lot of detail and learn a great deal about planetary physics out there." ☐

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AQUILA

DESCRIPTIVE NOTES (Cont'd)

to resemble the spectrum of a diffuse nebula. The appearance is not permanent, however, and after a number of years the expanding gaseous shell fades to invisibility, leaving the former nova as a faint white-hot star, considerably smaller and denser than the Sun.

The chief stages of a nova outburst are indicated on the schematic diagram below. The "initial rise" of 8 or 9 magnitudes is usually accomplished in a few days, and is often followed by a short "pre-maximum halt" lasting for a number of hours. This feature is not always present, or at least is not always detected. The final rise to peak brilliancy then follows at a slightly lower rate, and increases the brightness by another magnitude or two. Various stars display individual peculiarities; Nova Aquilae and Nova Puppis (1942) were typical "fast novae" with a single sharp maximum and a rapid decline, whereas Nova Aurigae (1891) and Nova Herculis (1934) remained near maximum for a number of weeks. In 1925, Nova Pictoris had three maxima spaced out over a period of nearly 10 weeks.

During the first 1 to 3 months after maximum, the typical nova fades by about 3½ magnitudes. This period is called the "early decline" and is followed by a 2 to 3 month "transitional phase" where stars again show their individual behavior. Some merely continue to fade rather

SCHEMATIC LIGHT CURVE OF A NOVA, SHOWING TYPICAL STAGES

NOVA AQUILAE 1918. The star is shown before the outburst, and shortly after maximum in June 1918. Photographed with the 42-inch reflector at Lowell Observatory.

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Astronomy 9/89

A Planetary Comeback: Magellan Heads for Venus

After a hiatus of twelve years, the United States is back in the planetary exploration business with May's successful *Magellan* launch.

by David S. F. Portree

Oddly enough, the launch delay imposed on the *Magellan* Venus probe by an equipment failure on the space shuttle was to the mission's advantage. Wisely anticipating some delay, NASA scheduled the launch of *Atlantis* (STS-30), with *Magellan* folded into its cargo bay, for April 28, 1989 — the first of a series of twenty-nine daily launch windows for *Magellan*. But as far as *Magellan*'s trajectory and approach to Venus were concerned, April 28 was *not* the most favorable launch day.

At a press briefing in March, *Magellan* project scientist Stephen Saunders of the Jet Propulsion Laboratory explained that an April 28 launch meant that *Magellan* would reach Venus travelling slightly too fast. Its Star 48-B solid-rocket motor would not be able to brake the spacecraft into the proper 3-hour and 9-minute radar-mapping orbit by itself. The orbital period would have to be shortened using *Magellan*'s onboard hydrazine fuel supply. This would leave less fuel for the thrusters that adjust the attitude-control momentum wheels, responsible for somersaulting *Magellan* around the planet more than two thousand times during its 243-day primary mission. Just as important, as far as the planetary scientists were concerned, there would be less fuel for the as-yet unfunded extended mission starting in April 1991. This supplementary mission is designed to fill in the gaps in radar coverage left after the primary mission.

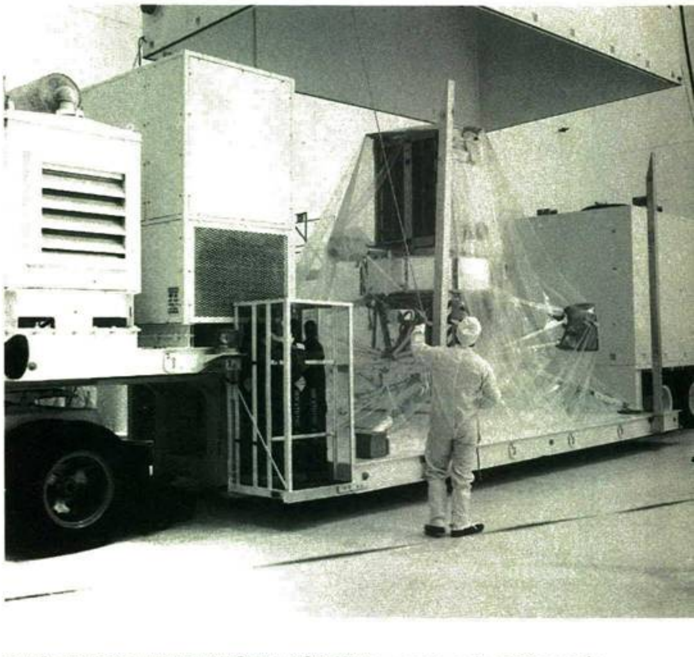
Saunders said a May 4 or 5 launch would be best for *Magellan*'s mission. Nevertheless, the April 28 scrub — the result of the failure of a pump buried within the labyrinthine plumbing in *Atlantis*' aft compartment — was a tremendous disappointment for the Kennedy Space Center teams. But, on the bright side, the delay made the May 4 launch possible.

Of course, had all gone as planned on that January day over three years ago, *Magellan*'s original launch might have been little noticed. But the grounding of the shuttle fleet in the wake of the *Challenger* accident caused *Magellan* to miss its first launch opportunity in April 1988. The next good launch window was October 1989. However, as Stephen Saunders put it, "We were good planetary citizens: We gave up our launch window for *Galileo*."

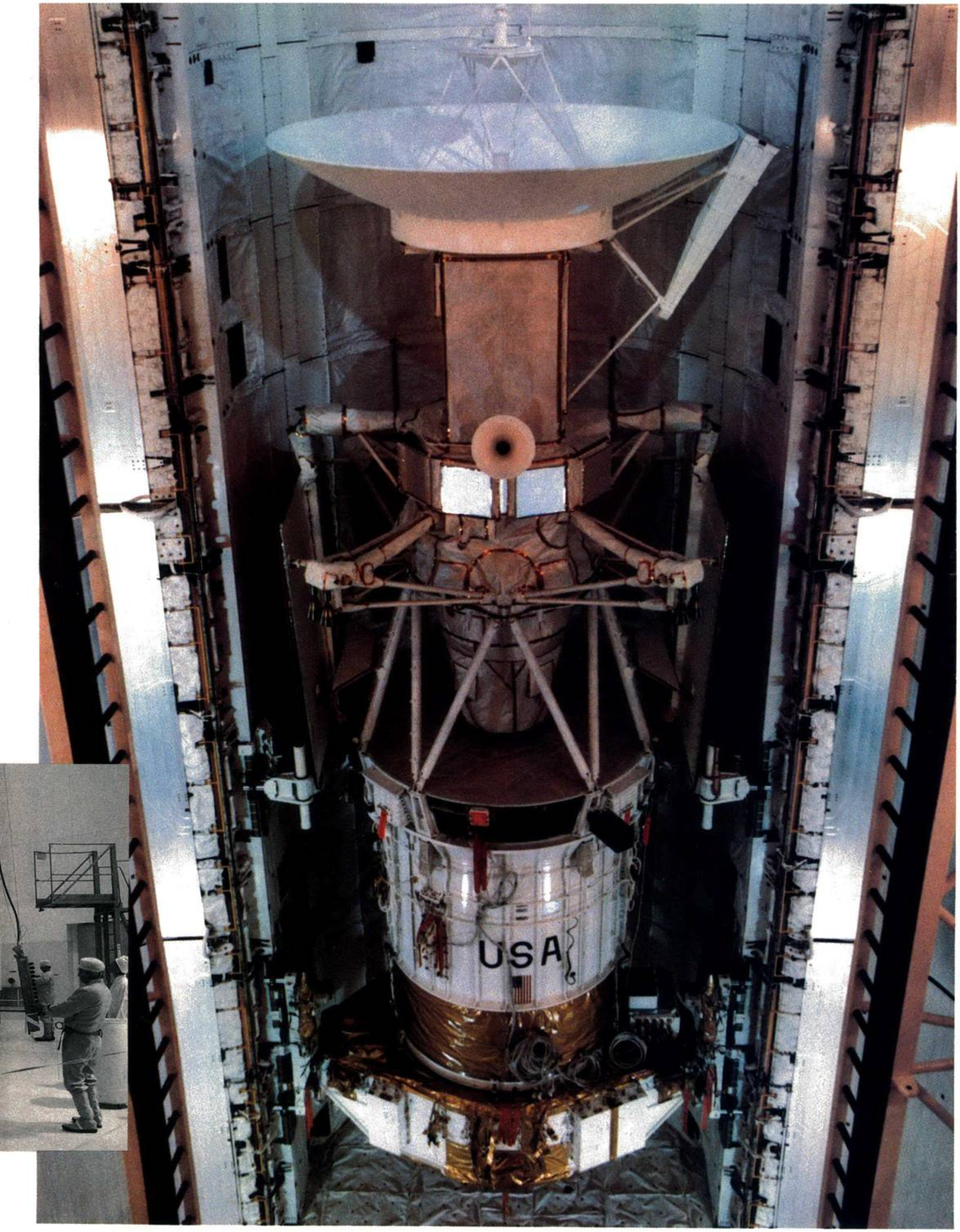
Launch schedules were further complicated by the subsequent cancellation of the liquid-fueled Centaur booster, which was to thrust *Magellan* and the Jupiter spacecraft *Galileo* out of Earth orbit. NASA officials decided that the Centaur was too volatile to carry aboard the shuttle because of the danger of an explosion.

The *Magellan* team opted for the next-best 1989 window — late April or May. But this meant a fifteen-month trip to Venus, instead of the four-month journey originally planned. The decision also cut six months from the time available to fit *Magellan* with the more stable solid-fueled Inertial Upper Stage (IUS). Ultimately, these events centered attention on *Magellan*, making it the harbinger of a new era of U.S. planetary exploration, not to mention the first planetary probe to be launched from the shuttle.

On the night of the April 28 scrub it was still unclear how serious the recirculation pump failure aboard *Atlantis* would turn out to be. Nevertheless, the Planetary Society, a space advocacy organization dedicated to supporting the exploration of the planets, went ahead with its planned special program at Kennedy Space Center's Spaceport: USA visitor center. On hand were Stephen Saunders; Louis Friedman, executive director of the Planetary Society; and Gordon Pettengill, principal



MAGELLAN'S TRANSPORT COVER is removed at Kennedy Space Center so the spacecraft can be assembled before being loaded into *Atlantis*' cargo bay (opposite page).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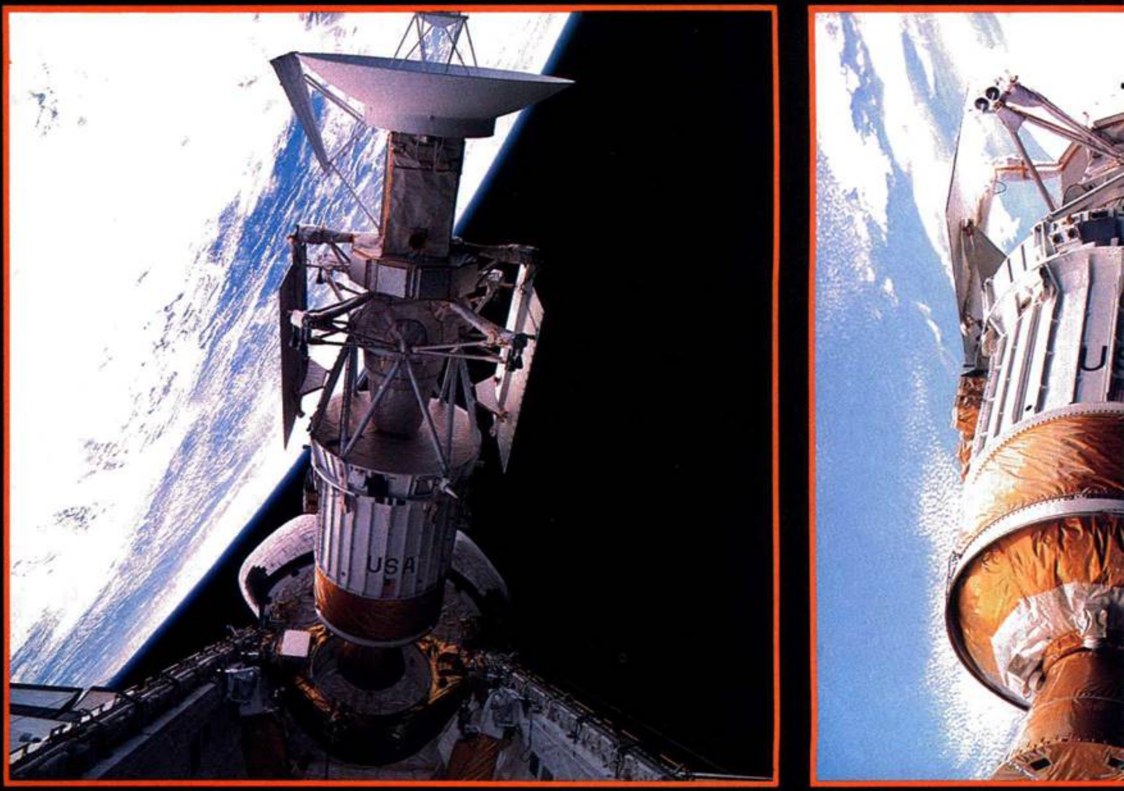
***MAGELLAN* RISES** from the shuttle's cargo bay to begin its 806-million-mile journey to Venus. These deployment scenes were photographed through *Atlantis*' aft flight deck windows with a hand-held 70mm camera. A couple of hours after releasing *Magellan*, shuttle astronauts photographed Venus shining like a beacon over Earth's western limb (below).



***MAGELLAN*'S SOLAR PANELS** deploy to power-up the spacecraft prior to leaving orbit. *Atlantis* glides home (left) after inaugurating the first U.S. planetary mission in over a decade.

investigator of the *Magellan* Radar Investigation Group.

A few hours before the start of the program, the scientists watched the gloomy press conference at which shuttle engineers described the failure of the pump and the sighting of a vapor cloud around the shuttle's fuel-line connection to the external tank. Faces were long; but the mood of the program was upbeat. Friedman pointed to the near-capacity crowd as evidence of a renewed interest in planetary exploration on the part of people all over the United States. "You couldn't turn out a crowd like this for a payload that was just a communication satellite," he declared. He jokingly called *Magellan* "old news," and pointed to upcoming shuttle-launched planetary missions for which *Magellan* is a trailblazer: *Galileo* and the joint European/U.S. *Ulysses* probe, designed to study the Sun's heliosphere as well as its never-before-seen south and north poles.

Stephen Saunders and Gordon Pettengill (Pettengill has been behind the Venus radar mapping mission since the early 1970s) were also upbeat. "We are confident we will launch during this opportunity," said Saunders.

He was right. On May 4, after a "Go" following weather delays, the countdown clock ticked down. At 2:47 p.m. eastern daylight time — with just five minutes of a 64-minute window remaining — *Atlantis* roared aloft. Stephen Saunders grinned broadly as he turned his face skyward and felt the wonderful thunder of the SRBs.

Six hours later, *Magellan* floated out of *Atlantis'* cargo bay, and one hour after that the two-stage IUS propelled *Magellan* out of Earth orbit at a velocity of 25,000 miles per hour. On May 21, when it was nearly 2 million miles from Earth, a mid-course correction was made to increase the spacecraft's velocity by a little over 66 miles per hour. Though it still has 24 million miles to go, *Magellan* is on its way and on schedule for an August 1990 rendezvous with Venus. ☐

David S. F. Portree is a freelance writer, artist, and photographer who lives in Winter Park, Florida.

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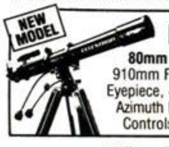

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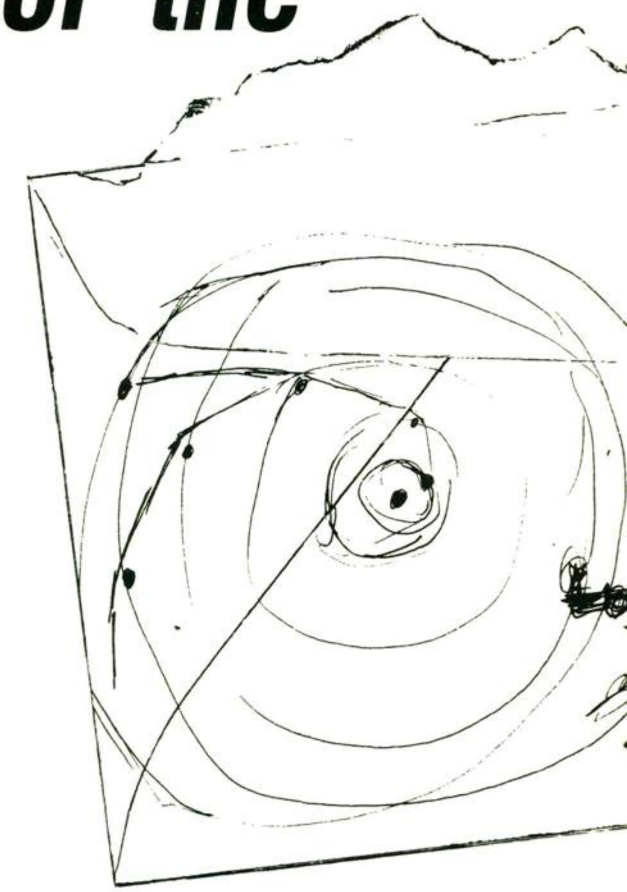
The Struggle for the Outer Planets



In the 1970s, tight budgets and disputes over NASA's program nearly doomed our chance to explore the outer planets.

by Craig B. Waff

The 1960s were a prosperous time for NASA. The build up of the Apollo lunar program along with the triumphant exploratory investigations of Venus and Mars with *Mariner* spacecraft seemed to affirm that NASA was capable of accomplishing anything and going anywhere in the solar system, even to the outer planets. These halcyon days fostered a euphoric can-do attitude among NASA administrators; ambitions and self-assurance were never higher.

The mood shifted after 1966, however, the year that the Apollo program reached its peak in developmental funding. NASA's annual budget began to decline from $6 billion in 1966 to about $3 billion by the early 1970s. Much of the funding decline can be attributed to social and political pressures on the federal budget at the time, such as the increasing fiscal demands of the Vietnam War and President Lyndon Johnson's "Great Society" programs. But the budget reductions also reflected NASA's deliberate postponement of serious planning of a post-Apollo program of manned and unmanned missions to the planets.

The agency, still preoccupied with its manned lunar landings, began to take post-Apollo program planning seriously only in early 1969, when the first landing was just months away. By then the fiscally conservative administration of Richard Nixon had taken power. The discussions of the mission concepts that would eventually evolve into the *Voyager*, *Galileo*, and *Ulysses* missions occurred at a pivotal moment in the history of the U.S. space program. The outer-planet exploration program we have today can be traced to this time, when grand aspirations and a growing record of successes in both manned and unmanned programs smacked against the wall of budgetary constraints and divergent goals in planetary exploration

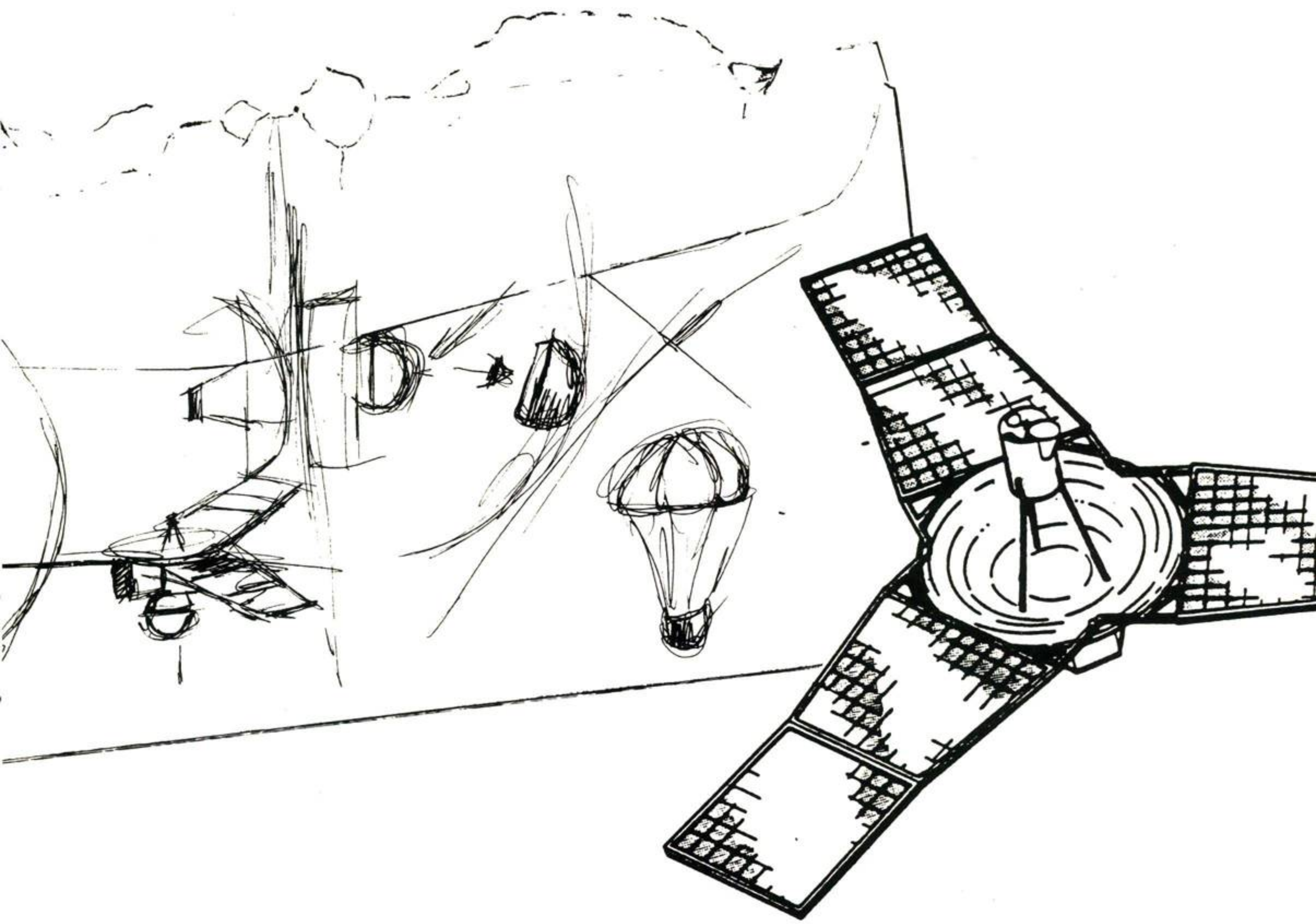
A Package Deal for the Planets

After the Jet Propulsion Laboratory (JPL), the Ames Research Center, the Goddard Space Flight Center, and the Marshall Space Flight Center had conducted initial outer-planet mission studies during the mid-1960s, mission planners readily agreed that the initial outer-planet missions (what were to become *Pioneers 10* and *11*) should be Jupiter flyby reconnaissances. These missions would assess the hazards of the asteroid belt and Jupiter's radiation, as well as conduct particle and field research. But it was not at all clear which missions to the outer planets NASA should pursue after Pioneer.

In a 1965 summer-study report, a panel of scientists organized by the National Academy of Science's Space Science Board outlined two directions that could be taken following the Jupiter missions: Either send reconnaissance flyby spacecraft to each of the more distant outer planets (Saturn, Uranus, Neptune, and Pluto), or embark on an intensive study of Jupiter through the use of orbiters and atmospheric entry probes.

As the technological challenges of these two programs were explored in the mid-1960s, a concept with the potential of making the first program more practical and less expensive was conceived and developed. Numerous mission analysts, beginning with Michael Minovitch, a UCLA graduate student working at JPL, examined an orbital tactic called "gravity assist" in which a spacecraft utilizes a planet's gravitational field to increase its velocity and alter its trajectory. Such a maneuver, the analysts determined, would not only reduce the launch-energy requirements that would otherwise be needed to reach a more distant planet via a direct flight, but it would also greatly reduce the trip time.

Some researchers immediately saw an opportunity for NASA to reap a scientific harvest from the planets using the gravity assist maneuver. In the late summer of 1965, Gary Flandro, a Caltech graduate student working at JPL, demonstrated that Jupiter, Saturn, Uranus, and Neptune would soon be positioned in such a way as to allow a single spacecraft, launched during any one of



five annual launch windows in the 1976-80 period, to encounter all four planets. Moreover, the entire mission could be accomplished in a greatly reduced time frame — about eight to thirteen years, depending on the trajectory, compared with thirty years for a direct flight to Neptune. Flandro dubbed the potential mission the "Grand Tour."

Public attention was first drawn to the Grand Tour with a December 1966 *Astronautics and Aeronautics* article by JPL's Homer Joe Stewart. This article, in turn, spawned articles in national newspapers.

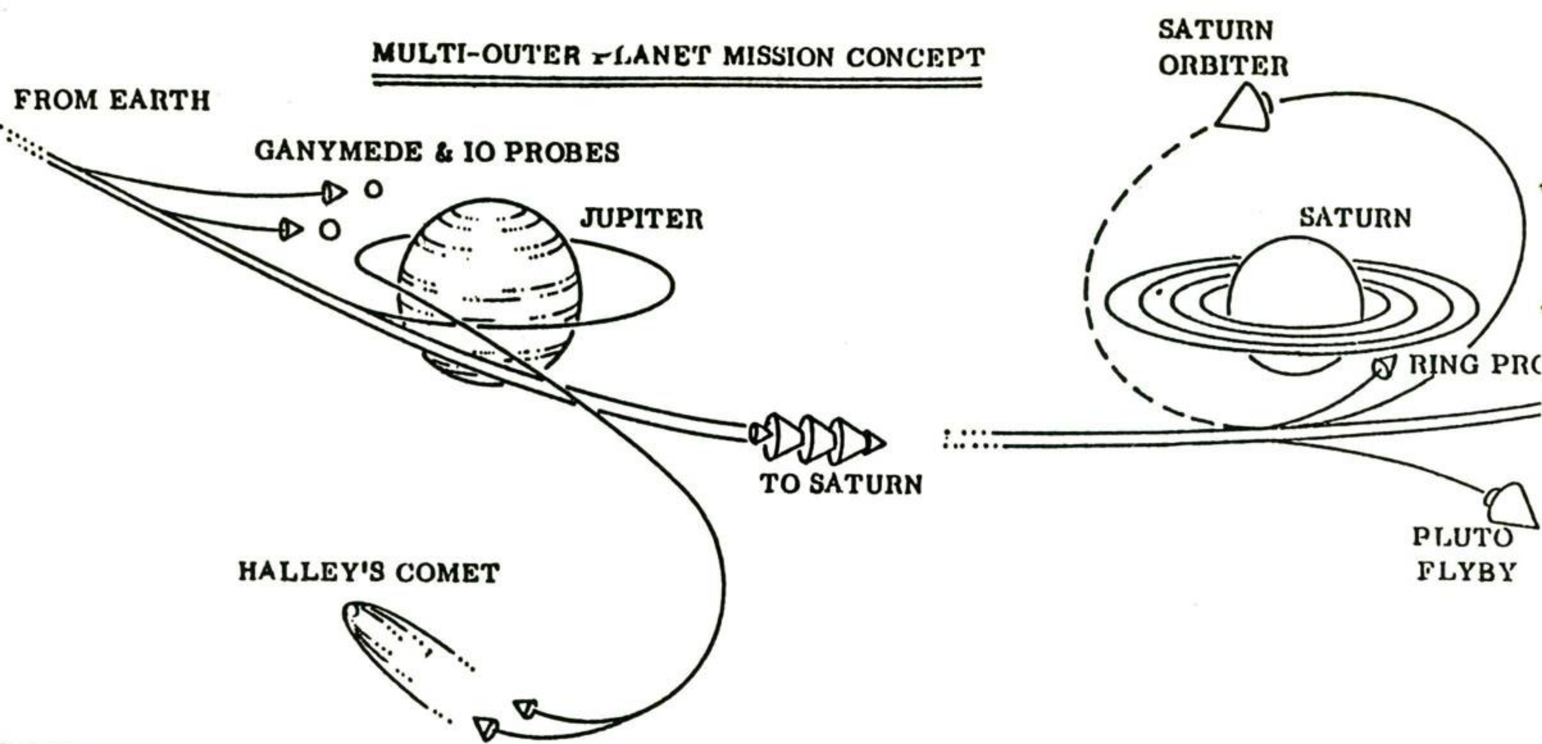
Emboldened by this unusual public attention to a space mission still in the early planning stage, JPL began advertising for new employees as early as March 1967 by promising that "We're going to give Jupiter, Saturn, Uranus, and Neptune the run-around. Join us on Project Grand Tour."

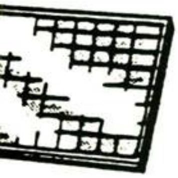
At NASA headquarters, planetary program officials needed little convincing that the Grand Tour concept merited further study funding. Donald Hearth, who at the time was program manager for advanced programs and technology in the Planetary Programs Office, recalled that the Grand Tour struck him as a mission that had "incredible sex appeal" and was a wonderful way to accomplish a first-reconnaissance mission to a variety of planets.

A major aspect of the mission's "marketability" was derived from the rareness of the Grand Tour opportunities, which occurred at intervals of approximately 175 years. It provided a compelling answer to the "Why-fund-it-now?" question that federal budget officials always asked. To drive home the point, Hearth noted that the last set of Grand Tour opportunities had occurred when Thomas Jefferson was president.

Hearth eagerly allocated $240,000 in fiscal year (FY) 1968 funding for advanced mission studies of the Grand Tour mission at JPL and the Illinois Institute of Technology Research Institute's (IITRI) Astro Sciences Center, which functioned from 1963 to 1972 as the Planetary Programs Office's "think tank." Despite its promotional appeal, however, Hearth reckoned that the Grand Tour might not necessarily be the most desirable post-Pioneer mission for planetary scientists, the group that would benefit most directly from any new mission. Thus Hearth provided funding for advanced studies of other outer-planet mission concepts, particularly orbiter and atmospheric entry-probe missions to Jupiter.

In looking at the viability of the gravity assist





maneuver and the use of atmospheric entry probes, mission analysts broached two main concerns. Even before the JPL and IITRI studies of the Grand Tour began, Brent Silver of Lockheed had pointed out that the most critical encounter of the Grand Tour would occur at Saturn. He calculated that in order to gravitationally bend its trajectory toward Uranus, the spacecraft had to pass near Saturn at a distance that was in the same range as the radius of the planet's rings. This brought up the dire possibility of a catastrophic collision of the spacecraft with ring particles.

There were just two options. If the spacecraft could make an interior passage (between the rings and the planetary "surface") the guidance requirements would be severe. An exterior passage (outside the rings) would be safer but would add three years to the flight time. A more palatable alternative was provided in 1968 by JPL mission analyst Dick Wallace. He explored the possibility of sending one of the spacecraft on a trajectory without a Saturn flyby: a Jupiter-Uranus-Neptune mission. In order to make up for the loss of a Saturn flyby and also to seek a way to fly by Pluto, Wallace later examined Jupiter-Saturn-Pluto trajectories. Unlike the four-planet Grand Tour, the three-planet trajectory would not require the hazardous passage near Saturn's rings.

Meanwhile, IITRI's J. E. Gilligan, beginning in 1967, was considering various types of Jupiter atmospheric entry probe missions. A successful entry, he said, would be "tremendously rewarding," but he warned that such an achievement would require "a substantial improvement in present technical resources." The reward would come from obtaining data on the composition and structure of the Jovian atmosphere that could not be obtained from ground-based observations or even from flybys and orbiters.

The biggest obstacle to overcome would be the probe's entry velocity. Because of Jupiter's tremendous gravitational pull, the entry velocity would be somewhere between 30 and 37 miles per second, several times larger than typical Earth entry velocities. Such a high velocity would heat the gas around the probe to temperatures ten times greater than those currently being handled in Earth and inner-planet entries. The heating of the probe at such velocities, Gilligan observed, "will be very severe — so severe in fact, that a large fraction of the initial vehicle mass will burn up."

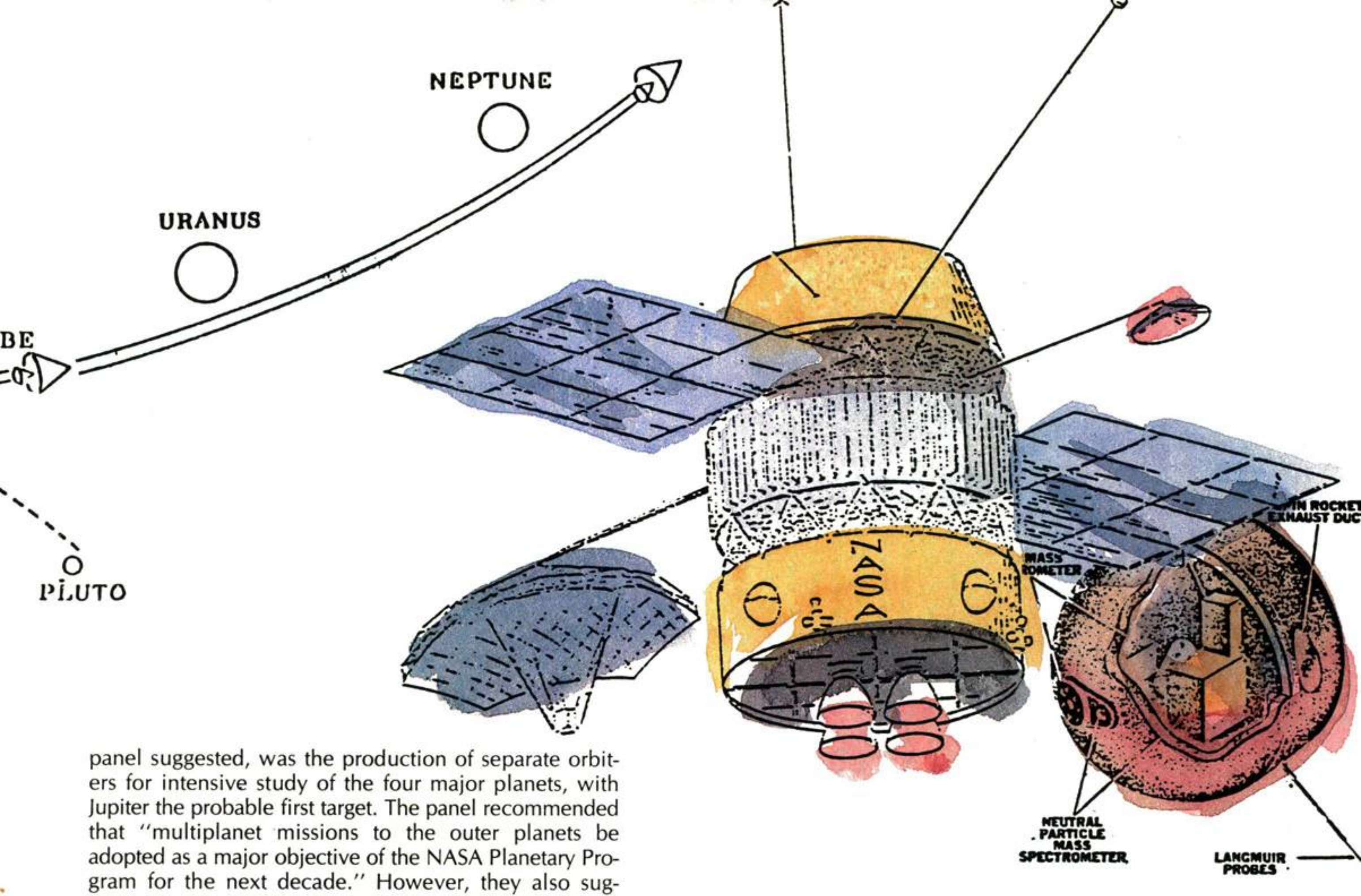
In addition to the multiplanet flyby and Jupiter entry-probe concepts, Jupiter orbiter mission studies had been started at both IITRI and JPL by early 1969. Thus, NASA officials had a variety of missions to Jupiter and the outer planets under consideration. Although multiplanet flyby mission concepts were furthest along, it was by no means certain that the scientific community would endorse these concepts or that NASA would approve them as the missions to follow the *Pioneer* Jupiter missions.

To Tour or Not to Tour

Securing scientific opinion on the most appropriate outer-planet mission was delegated to John Naugle, NASA's associate administrator for space science and applications. In early December 1968, Naugle asked members of the Lunar and Planetary Missions Board, a NASA-appointed science advisory group, to identify the scientific objectives for multiplanet missions and to suggest alternative strategies for exploring the outer planets. In response to Naugle's request, the board converted its Jupiter panel into the Panel on the Outer Planets. The panel was comprised of James Van Allen of the University of Iowa (who chaired the panel), Von R. Eshleman of Stanford, and Thomas Gold of Cornell, all of whom had helped formulate the scientific objectives of the Pioneer Jupiter missions.

In a report to the board two months later, Van Allen's panel agreed that the Grand Tour "has a considerable subjective and promotional appeal" and suggested that "it will constitute a technological and scientific *tour de force* of heroic dimensions." The panel also noted that there were substantial justifications for conducting a four-planet Grand Tour, such as the cost reductions and the increased quantity of information about the outer planets.

The principal alternative to the Grand Tour, the



panel suggested, was the production of separate orbiters for intensive study of the four major planets, with Jupiter the probable first target. The panel recommended that "multiplanet missions to the outer planets be adopted as a major objective of the NASA Planetary Program for the next decade." However, they also suggested that a broader consideration of NASA's future outer-planet exploration program be undertaken later in 1969 by way of a summer study cosponsored by the Lunar and Planetary Missions Board and the Space Science Board.

Such a study was subsequently scheduled for June. In the meantime, NASA sought advice from its field centers on formulating an exploration strategy that the agency would recommend to the summer-study participants. The agency thus organized an Outer Planets Working Group comprised of two representatives — generally a scientist and an advanced mission planner — from JPL, Ames Research Center, Goddard Space Flight Center, and Marshall Space Flight Center.

The Working Group rejected the idea of skipping the multiplanet flyby opportunities in favor of waiting until the development of a Jupiter orbiter, which they recognized as having "greater scientific potential." The multiplanet flyby missions were more attractive to the Working Group because they would survey all of the outer planets and permit "the accomplishment of many scientific objectives at relatively low cost." The group preferred the Jupiter-Saturn-Pluto and Jupiter-Uranus-Neptune tours over the four-planet Grand Tour because the pair of three-planet missions would permit visits to all five outer planets (including Pluto).

The group recommended that a test flight of the multiplanet mission spacecraft be launched in 1974 to fly by Jupiter and then swing out of the plane of the solar system using the planet's gravity. The gravity assist would reduce the flight time needed for the spacecraft to reach and probe the unexplored region between the solar system and the interstellar neighborhood.

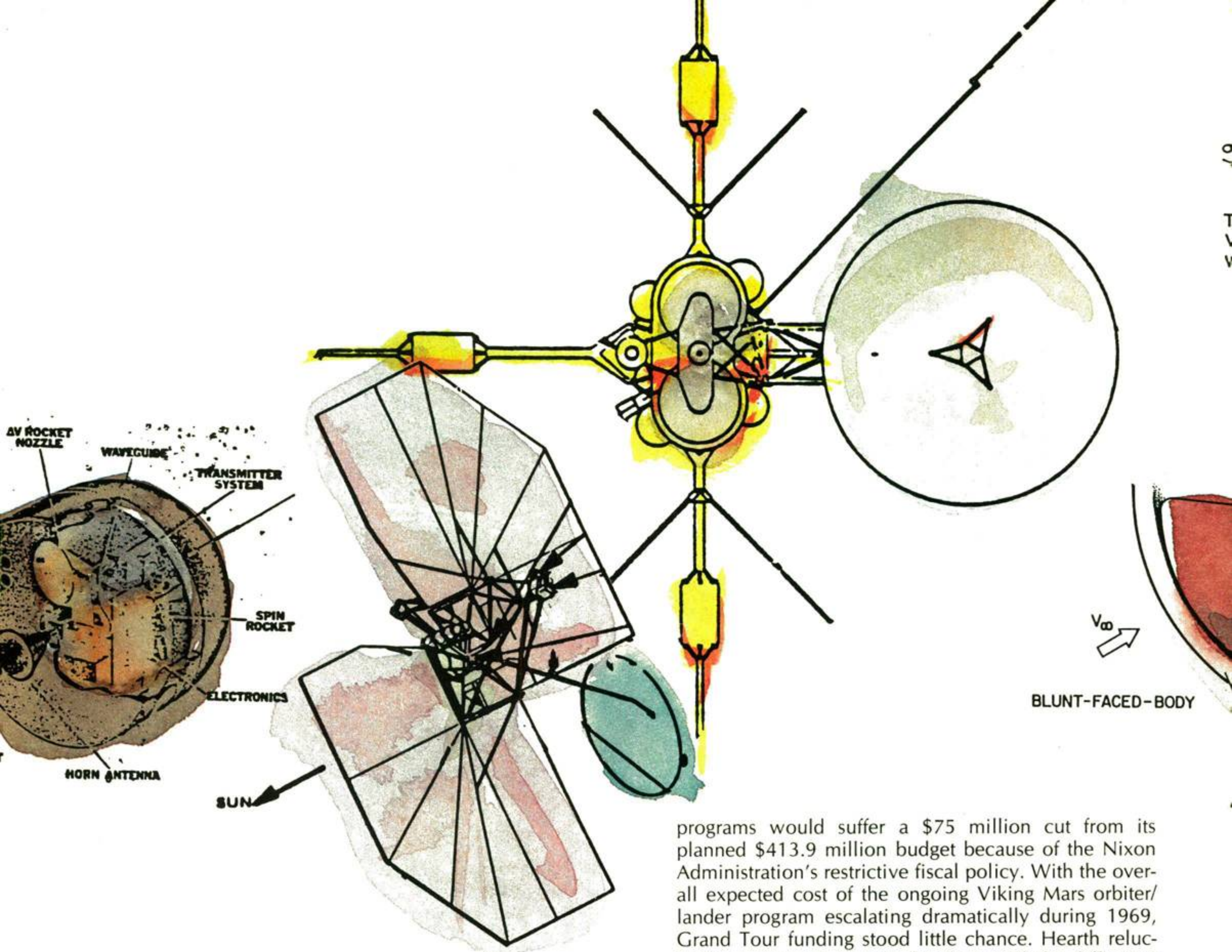
By May 1, 1969, the Working Group had developed an ambitious base program for surveying the outer planets:

- 1972 and 1973, *Pioneer F* and *G* (*10* and *11*) Jupiter flybys (already approved);
- 1974, Jupiter flyby/solar-system escape;
- 1977, Jupiter-Saturn-Pluto swingbys;
- 1979, Jupiter-Uranus-Neptune swingbys and follow-up of intensive exploration of Jupiter and Saturn;
- 1976-78, Jupiter orbiter;
- 1978-80, Jupiter multiple atmospheric entry probes;
- 1978-81, Saturn orbiter/multiple probes, interplanetary missions (out-of-ecliptic).

When the summer study convened that June, the twenty-three members were asked to consider the exploration of the outer solar system from 1972 to 1980. The five missions that they recommended were listed in order of scientific significance:

- 1974 or 1975, Jupiter deep-entry probe/out-of-ecliptic mission;
- 1976, Jupiter orbiter with deep-entry probe recommended;
- 1977, Jupiter-Saturn-Pluto missions, unshielded entry probe for unspecified planet;
- 1979, Jupiter-Uranus-Neptune missions with unshielded Neptune probe;
- Early 1980s, Jupiter-Uranus mission with deep-entry Uranus probe.

The panel, recognizing that any data about a planetary atmosphere obtained through remote sensing would have to be modeled after the physical conditions of the atmosphere, recommended an early direct probing of Jupiter's atmosphere. Such measurements would be used to validate or invalidate the results obtained from models and help interpret observations from flyby



and orbiter missions of other planets.

Although the Working Group in a subsequent meeting expressed skepticism that first-generation entry probes could be developed in time for flights in the 1974-1977 period, it did reverse the order of the Jupiter entry-probe and orbiter missions and suggested that they now be launched in 1978 and 1980, respectively. A 1981 Saturn-Uranus mission, which would deposit probes at both planets, was proposed in place of a Saturn orbiter.

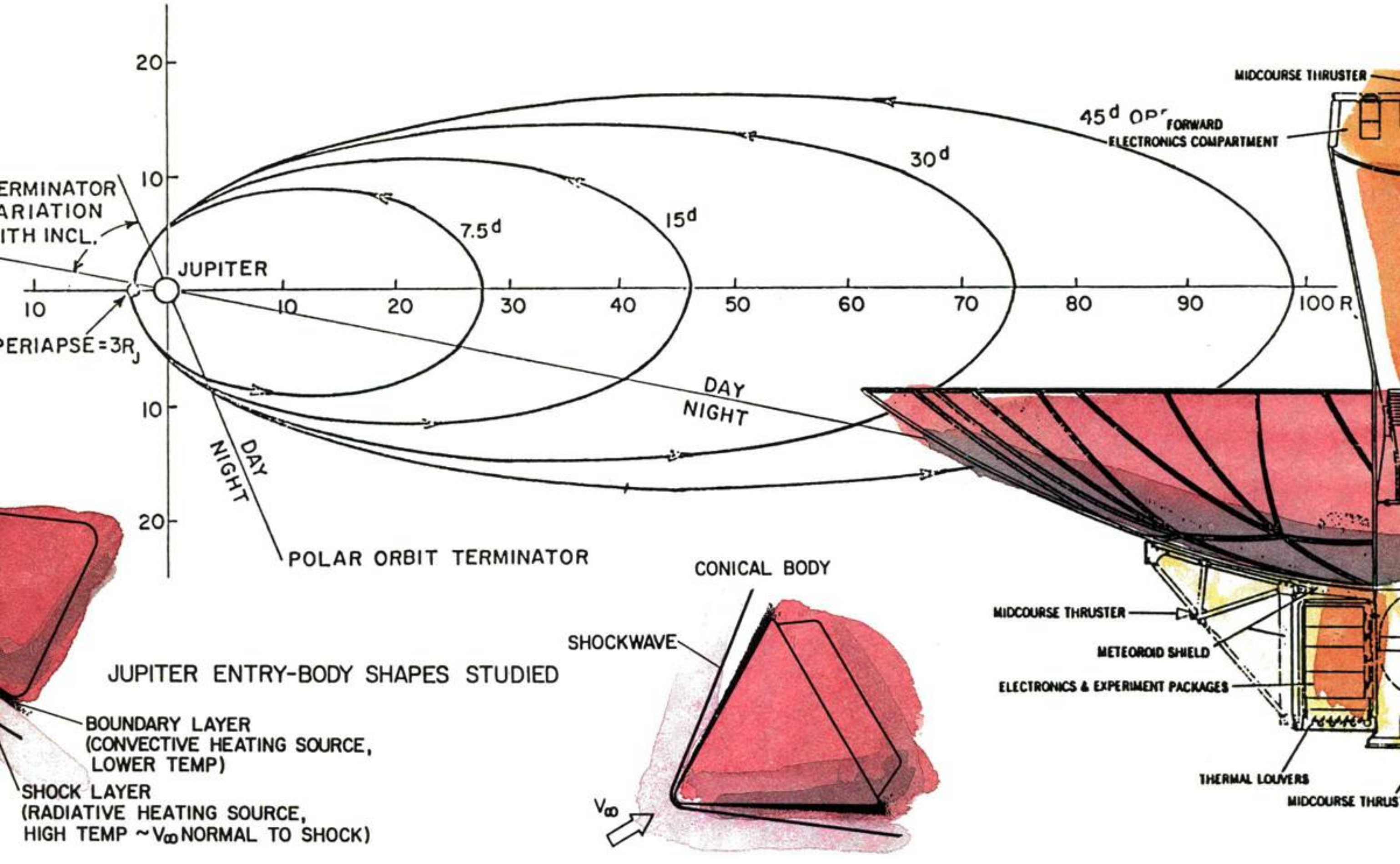
Based on the discussions of the Working Group and summer-study panel, NASA's Planetary Programs Office sought initial funding for the 1974 test flight and the 1977 and 1979 Grand Tour missions in the 1971 budget, which was being formulated by NASA in the summer of 1969 for submission to the Bureau of Budget in September. By mid-summer, however, the bureau, under the new, budget-conscious Nixon Administration, issued guidelines for the 1971 budget that did not bode well for NASA's ambitious plans for the post-Apollo period.

Divergent Philosophies

Start-up funding of $33 million for the Grand Tour and an additional $3 million for advanced studies of the subsequent outer-planet orbiter and probe missions were included in the September budget that the Office of Space Science and Applications recommended to NASA officials. But it soon became clear that NASA's planetary programs would suffer a $75 million cut from its planned $413.9 million budget because of the Nixon Administration's restrictive fiscal policy. With the overall expected cost of the ongoing Viking Mars orbiter/lander program escalating dramatically during 1969, Grand Tour funding stood little chance. Hearth reluctantly postponed start-up funding until the following year, which meant delaying the test flight from 1974 to 1975 and maintaining the momentum of the program via much smaller "supporting research and technology" funding.

The severe budget reductions that NASA's Office of Space Science and Applications was forced to make in the preparation of the 1971 budget led Philip Handler, president of the National Academy of Sciences, to suggest to NASA administrator Thomas Paine that a Space Science Board review panel be established to evaluate the balance among the scientific disciplines that NASA supported, namely planetary exploration, lunar exploration, astronomy, gravitational physics, solar-terrestrial physics, Earth environmental sciences, and life sciences. Paine accepted Handler's offer, and a broad-based summer study, involving nearly ninety scientists, was held at Woods Hole, Massachusetts, from July 26 to August 15, 1970.

The participants in this study divided themselves into the seven scientific-discipline groups. Each group was asked to recommend programs for its discipline within three budgetary levels: no change, a 25-percent increase, and a 50-percent increase. In addition, a fourteen-member executive committee, chaired by Space Science Board member Herbert Friedman of the Naval Research Laboratory, had the difficult task of combining the proposals of the working groups into an overall priority system.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Despite some areas of agreement — e.g., that the funding of a large program like the Grand Tour should not preclude smaller programs such as planetary explorer missions to Venus — the separate reports of the Planetary Exploration Working Group and the executive committee reflected conflicting philosophies of planetary exploration. The Working Group argued that the uniqueness of the Grand Tour opportunity was "so great that it should not be missed." By taking advantage of the Grand Tour, the initial flybys could observe as much as possible. Orbiter and entry-probe missions then could be planned for the 1990s, when they could take advantage of a set of Jupiter swingby opportunities and the expected development of nuclear-electric propulsion. If the Grand Tour opportunities were passed up, the group asserted, "we would have to postpone our entire program to explore the [trans-Jovian] outer planets by fifteen years."

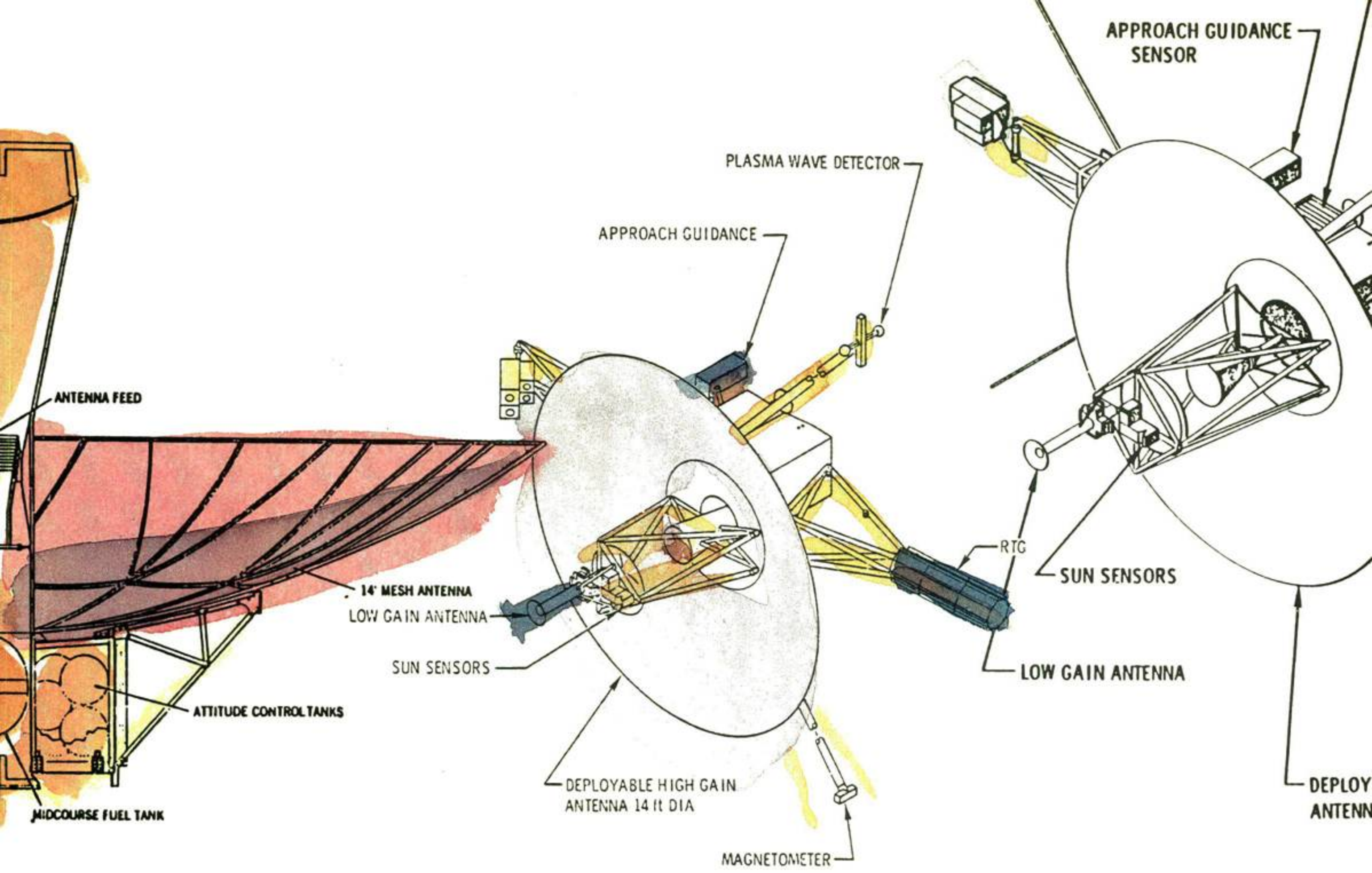
The executive committee, on the other hand, was more enthusiastic about Jupiter-intensive investigations, pointing out that "modern technology allows us to think in terms of entry probes, orbiters, and landers and of the many questions that might be answered with these tools." Citing an anticipated high yield of scientific data, the committee concluded that "a thorough investigation of Jupiter is, for the near future, the most rewarding objective among the outer planets and will contribute to the experience needed for successful missions to more distant planets at a later time."

The committee also viewed the Grand Tour missions as both technically and scientifically risky. Friedman argued that there was "serious doubt about the ability of components and systems to perform reliably over the long-duration missions." He also warned that "featureless cloud cover may obscure the ultimate view of the distant planets" and the trajectories of the missions would be "too highly constrained by the gravity-assist requirement to be optimized for inspection of the satellites" of the outer planets.

The initial drafts of the Working Group and executive committee reports were received by NASA officials in mid-August 1970. NASA, however, did not react to the reports immediately, probably because they were preoccupied with preparing the 1972 budget. Responding to a request from Deputy Administrator George Low to constrain Grand Tour funding in this budget, Naugle reluctantly dropped the 1975 test flight, thus losing the out-of-ecliptic mission. He also rescheduled one of the 1977 Jupiter-Saturn-Pluto missions to 1976, so that it would double as the test flight of the new Thermoelectric Outer Planet Spacecraft (TOPS), the sophisticated spacecraft that JPL was designing for the Grand Tour missions.

Finally, in December, after successfully beating back an Office of Management and Budget attempt to delay the Grand Tour startup to FY 1973, NASA officials began considering the executive committee's negative views regarding the mission. They anticipated that Congress would soon become aware of these views and question why NASA was proceeding with a program that a large part of the scientific community opposed. As a result of discussions between Naugle and the Space Science Board regarding this matter, NASA announced at its budget briefing in January that it would keep open until November 1971 the option of choosing the 1976/1977 Jupiter-Saturn-Pluto Grand Tour mission sequence, the Jupiter-orbiter missions during the same opportunities, or a combination of both.

With regard to Jupiter orbiters, one concern in particular needed to be addressed. Earlier IITRI (1968-69)



and JPL (1969) studies of Jupiter orbiters indicated that the scientific return could be maximized if two spacecrafts were used. A spinning spacecraft (such as Ames Research Center's *Pioneer*) would have an inclined orbit to obtain fields-and-particles data, and a three-axis-stabilized spacecraft (such as JPL's TOPS) would utilize an equatorial orbit for planetology and satellite encounters. Responding to executive committee concerns, Naugle now wanted a comparison of the costs and scientific values of this dual-mission mode with a backup plan of using *Pioneer*-class spacecraft and compromise orbits for both kinds of research.

Thus, during the spring of 1971, JPL and Ames conducted coordinated studies of Jupiter orbiters based on the TOPS and *Pioneer* spacecraft. The plan was to have JPL and Ames present their results during the summer to a newly appointed Space Advisory Group (Outer Solar System Missions), which NASA organized to develop mission strategies for total solar system exploration, and then to another Space Sciences Board panel on outer-planet exploration.

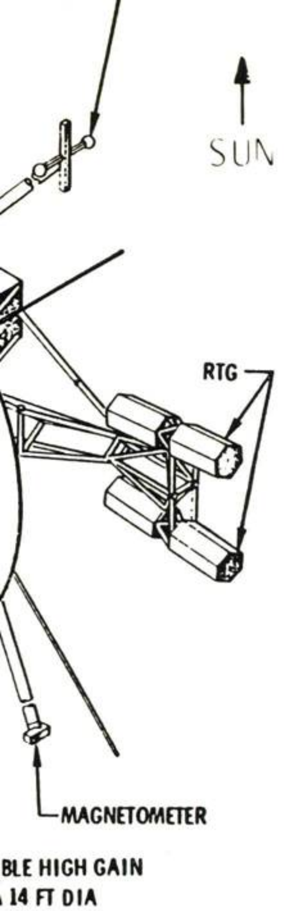
Budget Lowers the Boom

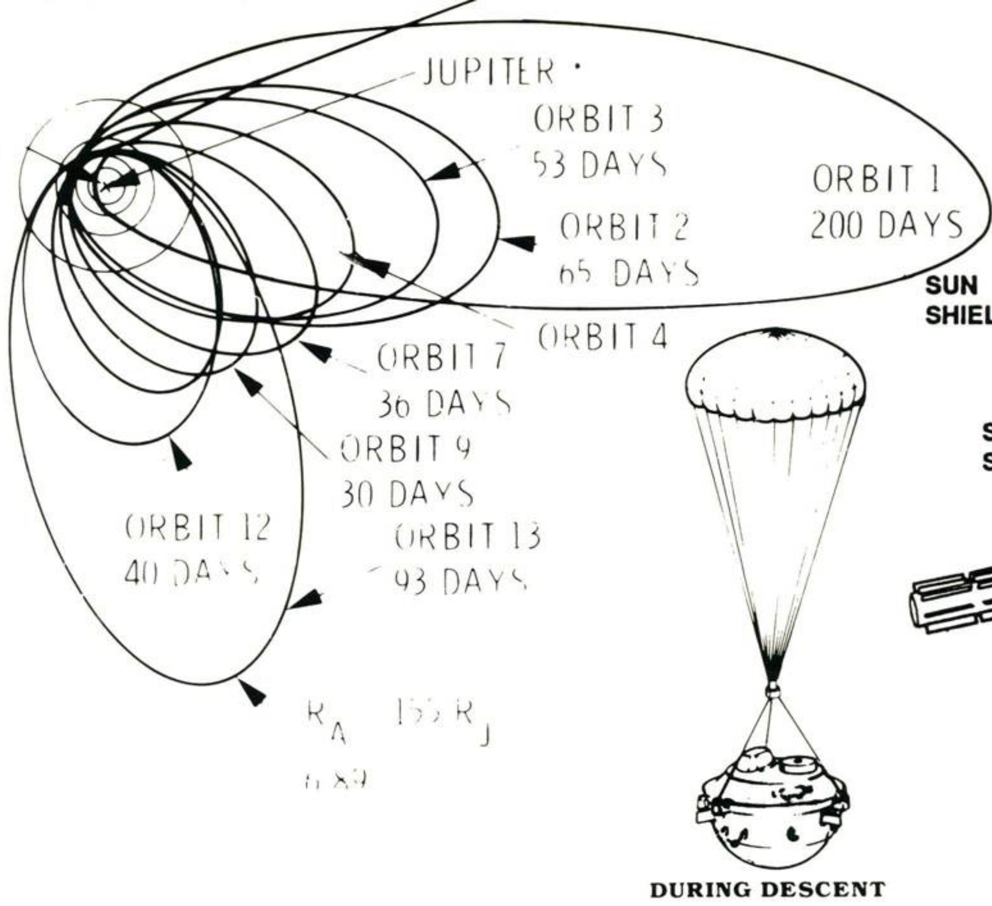
But the political fortunes of the Grand Tour faded even before the scientific panels met. Shortly after the "priorities" study report was issued on March 9, 1971, and perhaps because of it, the Office of Management and Budget asked NASA to study "simpler, less costly alternatives to the TOPS spacecraft for the Outer Planet Missions." (Outer Planet Missions was the name that NASA had given in the FY 1972 budget to a program that would now include Grand Tour flybys and Jupiter-orbiter missions.) A month later at a Senate budget hearing, Naugle and Low were asked a series of questions relating to whether NASA was responding properly to the conclusions and recommendations in the "priorities" report.

Their answers, apparently, were not persuasive. On June 8 the committee voted to reduce the Outer Planets Missions program from $30 million to $10 million. Although a subsequent House and Senate conference committee raised the authorization to $20 million, the conferees advised NASA to "examine the TOPS concept with the view to designing a less-sophisticated, less-expensive spacecraft for carrying out the Grand Tour missions in the latter half of the decade of the 1970s, and to consider subsequent opportunities to explore the outer planets during the 1980s and 1990s using vehicles incorporating the NERVA [nuclear engine for rocket vehicle application] engine."

On July 29 the Science Advisory Group met to hear separate presentations on Jupiter orbiters by the study teams from JPL and Ames. JPL stated that Option A — proceeding with the use of TOPS for four multiplanet Grand Tour missions — would cost an estimated $750 million. Option B — substituting two TOPS Jupiter orbiters in 1977 in place of two Jupiter-Saturn-Pluto missions — would cost about $925 million (the extra cost was due to the development of the retropropulsion system needed to insert the spacecraft into orbit around Jupiter). In the event that TOPS was not developed, JPL estimated that two *Mariner*-class Jupiter orbiters would cost $275 million, while Ames estimated that $158 million would be required to build two *Pioneer*-class Jupiter orbiters.

The next day the Science Advisory Group reported that it could reach "no clear consensus" on the scientific merits of the two options in the TOPS program. Option A had "broader exploratory appeal," yet Option B better served "those whose interests and inclinations





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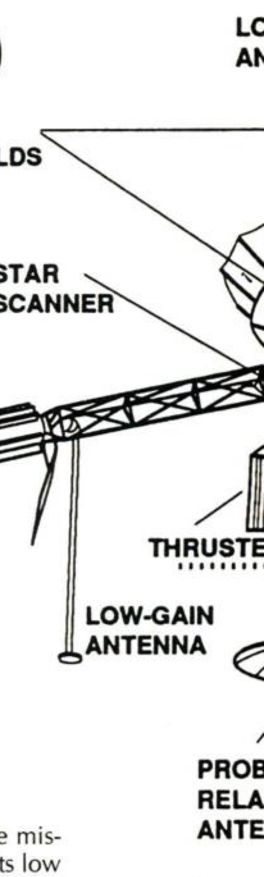


favor the view that more intensive investigation of Jupiter and its satellites will yield greater physical insight." For "principally practical" reasons, however, the Science Advisory Group recommended Option A with the 1976 Jupiter-Saturn-Pluto mission deferred to 1977. Option B, the advisory group stated, would cost 25 percent more and would require parallel spacecraft developments that would strain funding requirements throughout the mid-1970s.

The advisory group concluded that, in the event TOPS was not funded, "a diverse, high-quality program of outer solar system science can be done with either an Advanced Pioneer or an Advanced Mariner." If such a fall back program was necessary, the group suggested two Jupiter-Saturn missions in 1977 and two Jupiter orbiters in 1979 or later, depending on the outcome of *Pioneers F* and *G* (*10* and *11*).

The group's recommendations were subsequently presented to the Space Science Board summer study on outer-planet exploration, which was held in August 1971. According to Robert Kraemer, who had succeeded Hearth as the Planetary Programs Office manager the previous year, the study members engaged in a "tough week of serious debate."

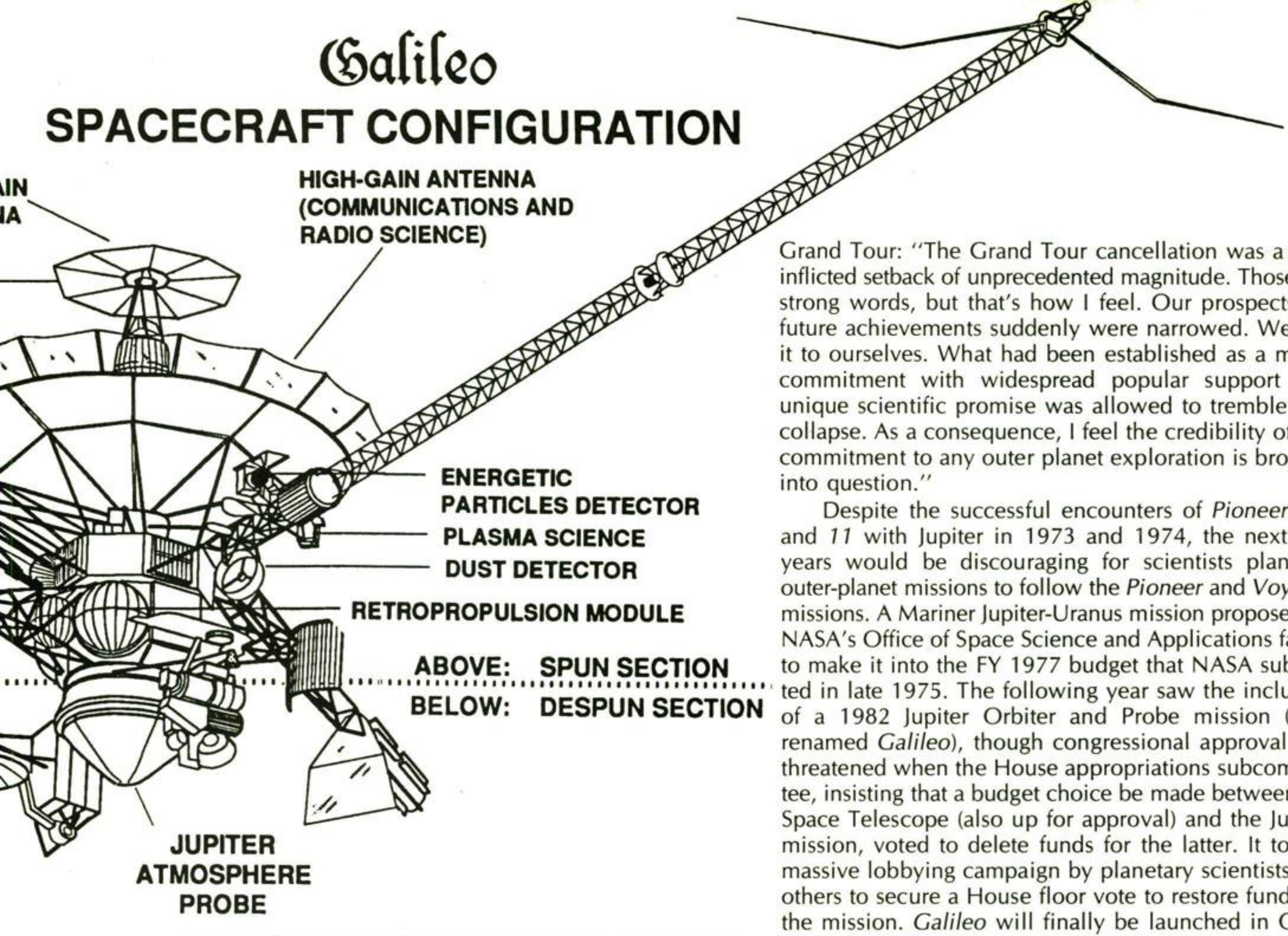
The 1971 summer study panel took no sides on the first-look versus intensive-investigation dispute, concluding that "a program combining TOPS Grand Tour with the more intensive study of Jupiter and Saturn with flybys, probes, and orbiters is fully justified" to maintain a desired program of outer-planet exploration. The panel realized, of course, that in the real world of NASA budgets the funding of both the TOPS and Pioneer programs might not be possible.

Like its 1970 predecessor, the summer study panel recommended that NASA maintain a Pioneer program at all budget levels, regardless of the fate of the Grand Tour program, and suggested a launch rate of one mission every two years. Part of Pioneer's appeal was its low cost, but it also had another virtue that TOPS Grand Tour spacecraft by definition did not: "*Pioneer*-type spacecraft can be handled relatively flexibly, without unduly restrictive time schedules and with maximum opportunity to respond to the results of previous missions. We regard this feature as highly desirable because it corresponds closely to the optimum *modus operandi* of the science community."

Ironically, the 1970 and 1971 Space Sciences Board panels then stated that the rareness of the Grand Tour opportunities — one of the features that NASA viewed as enhancing the "marketability" of this mission — imposed an inflexible schedule that constrained the normal process of scientific research.

In the opening round of discussions regarding NASA's 1973 budget, the Office of Management and Budget proposed a ceiling of $2.975 billion in outlays. New NASA Administrator James Fletcher countered in late September 1971 with a "minimum recommended program" requiring $3.225 billion in outlays. The advice of several scientific groups, Fletcher remarked, had convinced him that the Grand Tour should proceed "not only for its scientific value, but also because I believe it will have great popular interest as mankind's farthest reach out into space." The Grand Tour was thus included in the budget, but its FY 1973 funding was reduced from an originally planned $100 million to $29 million. The total program funding dropped from $1 billion to about $750 million. The scale of the experimental payload was also reduced.

Fletcher argued that if NASA was held to the suggested Office of Management and Budget's ceiling, he would have to cancel at least one major ongoing program. His reluctant choice would be the *Apollo 16* and



Galileo
SPACECRAFT CONFIGURATION

17 lunar flights rather than Skylab or *Viking*, which were "unique first-of-a-kind missions." New programs such as the space shuttle and Grand Tour would also have to be cancelled "because it is clear that neither of those programs could realistically be supported in future years at a budget at or close to the level proposed by the Office of Management and Budget for 1973."

On December 11, Fletcher learned from White House officials that President Nixon was prepared to approve the space shuttle program. Apparently at about the same time, the president let it be known that NASA could not simultaneously fund both the shuttle and the full four-mission TOPS Grand Tour spacecrafts in the 1973 budget and especially later years, when the budgets of both programs would simultaneously grow. As a result, shortly before Christmas NASA and the Office of Management and Budget terminated the TOPS effort. The demise of the TOPS Grand Tour program and the substitution of more modest Jupiter-Saturn flybys by a pair of less expensive *Mariner*-class spacecraft (later named *Voyagers 1* and *2*) were publicly announced in the president's budget message of January 1972.

At a NASA budget briefing and news conference, Fletcher explained that because of a "less than an enthusiastic response from certain elements of the scientific community particularly, and to some extent Congress, it didn't make sense to commit that large an amount of dollars to the planetary program." His deputy, George Low, argued that "the simple truth is that there wasn't unity among scientists regarding the value of the Grand Tour, and this made it an easy target for cancellation."

In testimony before Congress a few months later, Bruce Murray — a space scientist who later became JPL's director from 1976 to 1982 — perhaps best summed up the disappointment of those who had advocated the Grand Tour: "The Grand Tour cancellation was a self-inflicted setback of unprecedented magnitude. Those are strong words, but that's how I feel. Our prospects for future achievements suddenly were narrowed. We did it to ourselves. What had been established as a major commitment with widespread popular support and unique scientific promise was allowed to tremble and collapse. As a consequence, I feel the credibility of our commitment to any outer planet exploration is brought into question."

Despite the successful encounters of *Pioneers 10* and *11* with Jupiter in 1973 and 1974, the next few years would be discouraging for scientists planning outer-planet missions to follow the *Pioneer* and *Voyager* missions. A Mariner Jupiter-Uranus mission proposed by NASA's Office of Space Science and Applications failed to make it into the FY 1977 budget that NASA submitted in late 1975. The following year saw the inclusion of a 1982 Jupiter Orbiter and Probe mission (later renamed *Galileo*), though congressional approval was threatened when the House appropriations subcommittee, insisting that a budget choice be made between the Space Telescope (also up for approval) and the Jupiter mission, voted to delete funds for the latter. It took a massive lobbying campaign by planetary scientists and others to secure a House floor vote to restore funds for the mission. *Galileo* will finally be launched in October of this year.

A year later, a 1983 International Solar Polar Mission (ISPM) was also approved. This mission proposes to send two spacecraft, one built by NASA and the other by the European Space Agency, on out-of-the-ecliptic trajectories. Although budget cutbacks in 1981 by the Reagan administration forced NASA to terminate its ISPM spacecraft, the Europeans continued development of their craft, later renamed *Ulysses*. The launch is slated for October 1990.

Voyagers 1 and *2*, launched in 1977, both had successful encounters at Jupiter and Saturn. Careful mission planning and the durability of the latter spacecraft allowed *Voyager 2* to flyby Uranus in January 1986. If *Voyager 2* remains operative through the Neptune encounter, it will have completed the four-planet Grand Tour that Gary Flandro conceived twenty-four years ago.

Although many changes have been made to the *Voyager*, *Galileo*, and *Ulysses* missions over the years, the basic concepts of multiplanet (Grand Tour) "first look" exploration, Jupiter-intensive investigation, and out-of-the-ecliptic surveying have remained at the core of the missions' scientific objectives. Perhaps more ambitious missions could have been undertaken had circumstances been different. We can, however, be grateful for the long and labored deliberations two decades ago that allowed solar system exploration to remain alive in the 1980s and give promise to the 1990s. ☐

Craig B. Waff is a science historian working under contract at the Jet Propulsion Laboratory. His article is based on research he conducted for a history of the Galileo *program. He is now working on a history of JPL's Deep-Space Network.*

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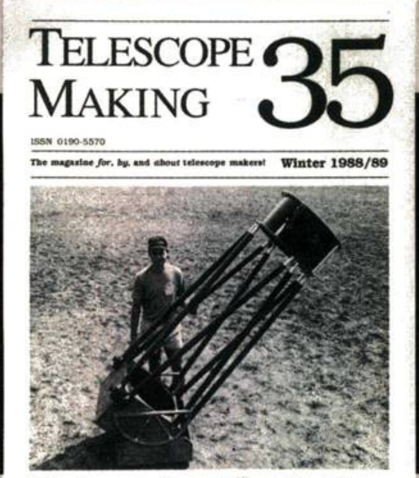
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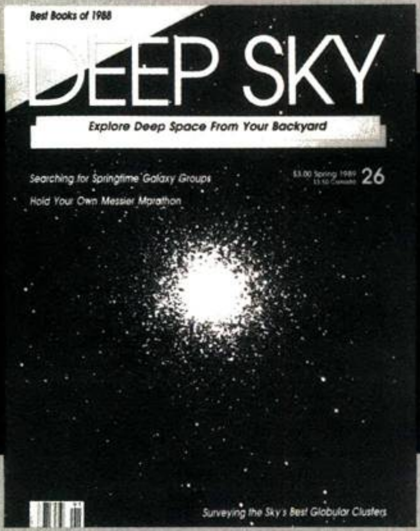
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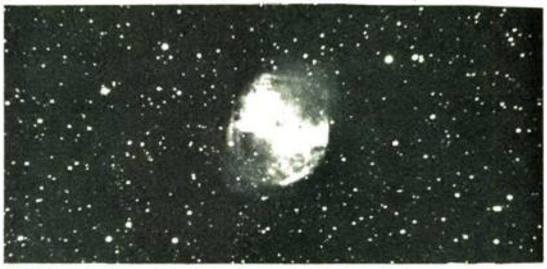

The "Dumbbell Nebula," M-27 in Vulpecula. The "ears" of the Dumbbell are seen best visually with a Lumicon UHC Filter. Photo by David Healy using a Lumicon Giant EASY-GUIDER and Lumicon hypersensitized 2415 film, 30 min., C-14 at f/6.

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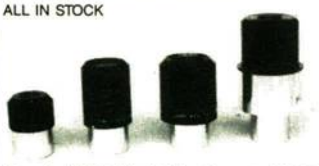

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NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. 1.3-1.8" mirrors have enhanced silver coatings (98-99%R). the extra 8-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$29.95** 1.52" **$34.50** 1.83" **$39.50**
2.14" **$49.50** 2.60" **$65.00** 3.10" **$89.50**
4.25" **$149.50**

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with 98-99% reflectivity enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

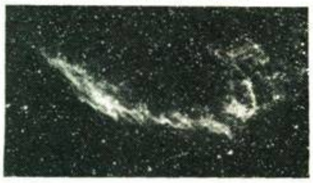
1¼" (1.32" mirror) **$99.50**
2" (1.83" mirror)(see photo above) .. **$159.00**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 90-97%.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*

Zepernick, Cresskill, NJ

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter or the LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 85-95%.

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$79.50
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$199.50
Set of Both premium **DEEP-SKY** and **UHC Filters** (Save 11%), Premium	$159.50
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. 1¼" **$99.50, 48mm**	$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines **1¼" $99.50, 48mm**	$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$20.00

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

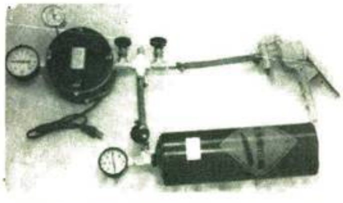
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$295**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.

Specify Camera and Telescope type.

U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER **$169.50**
3X Relay Diagonal (see photo) **$89.50**
Illuminated reticle eyepiece system .. **$99.50**
Guider for Hasselblad **$350,** Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$195,** Mamiya **$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector . $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.

Declination motor (state telescope) .. $99
NEW Deluxe Digital Qtz. Drive Correc. **$298**

Kodak
SR1600
Scotch
Scotch
1000
NEW
SRV3200

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	$10.95
SRV3200, fastest of all, color neg	24	$13.95
Konica WR3200, unhypered	24	$8.50
Konica SR400, fine grain color neg	12	$10.95
3M 1000, fastest slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

LUMICON means INNOVATION

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550
(415) 447-9570
FAX (415) 447-9589

LUMICON® SKY VECTOR™- *NEW!*

Computer-Controlled Digital Setting Circles, only $498

Sky Vector ™
ON OFF
2137+490
DIM
RA
DEC
MODE
STAR
LUMICON

LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). The coordinates are for Minkowski 1-79, a 13th mag. planetary nebula.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a breakthrough in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

Incredibly Smart!
thus
Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
- Digital decl. readout to 10 arc-min
- Digital altitude readout to 1°
- Motor drive ***not required!***
- Polar alignment ***not required!***
- Just sight two stars!

The computer's sophisticated program (over 3000 lines of code) determines **everything** from an initial sighting of just two stars!

- **No need** to enter latitude, longitude, sidereal time, date, etc.
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080. The computer automatically knows the difference.
- Uses Epoch 2000.0, 1975.0 or 1950.0 coordinates.
- Light weight, only 2 oz. permits mounting near the eyepiece, if desired. Only 2.6"x2.6"x1".
- 9V Battery lasts many nights.

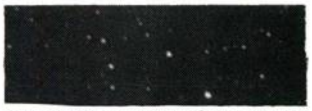
LUMICON SKY VECTOR™ for Meade 2080,2120,C-8,C-11, *(Specify)* **$498**
For Celestron-14 .. **$575.** For any alt-azimuth (Dobsonian) telescope .. **$498**
For Coulter Odyssey 8", 10", 13", 17½" *(Specify telescope)* **$498**
SKY VECTOR KIT. You must supply adapting hardware. For skilled ATM's only **$449**

Reference catalogues listing coordinates of 1000's of objects

Burnham's *Celestial Handbook,* Vol. I, II, III (Epoch 1950.0)	**$36.85**
The *Revised New General Catalogue* (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II, doubles, variables, deep-sky objects	**$29.95**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

1.5x, 1.8x MULTIPLIER LENS

1.8x Multiplier Lens

THe computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. It multiplies by 1.5x without the included extension tube. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.5x/1.8x multiplier lens **$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM
$49.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion low profile focuser	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

MEADE® TELESCOPES

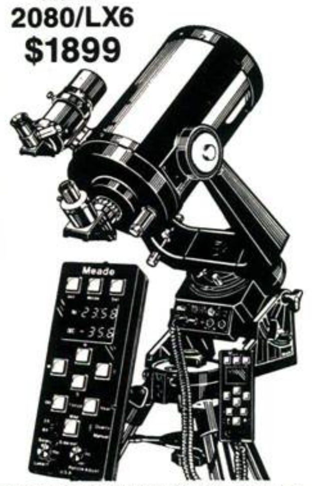
LUMICON, 2111 Research Dr., #5, Livermore, CA 94550
(415) 447-9570
FAX (415) 447-9589

LUMICON ACCESSORIES

2080/LX6 8" f/6 .. $1899
2120/LX6 10" f/6 . $2499

Digital readout system for 2080/2120/LX6	**$399**
8200 object memory CAT computer	**$999**

NEW 2080/LX6 $1899



Meade Model 2080/LX6: The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89; 32mm $109**
Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**
Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2080 Original 8" f/10 w/tripod	**$999**
2080/LX3, 8" f/10 w/MCOG	**$1389**
2080/LX5, 8" f/10 w/MCOG	**$1599**
2120/LX5, 10" f/10 w/MCOG	**$1995**
2120/LX3, 10" f/10 w/MCOG	**$1799**
2045/LX3 4" f/10 w/LX3 drive	**$795**
#39 declination motor for LX5	**$109**
#38 (LX3) or #38A (2045) dec. mtr.	**$99**
Dew shield - essential! 8" **$65;** 10"	**$98**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

48mm COLORED GLASS FILTERS

These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2" eyepieces. Use adapter for 1¼" eyepieces. AR Coated.

Filter:	Bandpass	Trans	2"	1¼"
Ultraviolet	320-420nm	85%	**$35**	—
UV Block	390nm-IR	98%	**$18**	—
Minus Violet	420nm-IR	96%	**$29**	**$18**
Blue Tricolor	340-470nm	80%	**$35**	**$18**
Hi Perf. Blue	300-540nm	95%	**$35**	—
Yellow	480nm-IR	98%	**$18**	**$18**
Green	490-590nm	60%	**$18**	**$18**
Orange	560nm-IR	98%	**$18**	**$18**
Red	600nm-IR	98%	**$18**	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**	—
Cyan	340-580nm	95%	**$59**	**$29**
Polarizer	340nm-IR	40%	**$20**	**$18**

Adapter for 1¼" eyepieces **$20**
Set of all 11 48mm filters ($318 list) **$275**

EYEPIECE PROJECTION

These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT.	**$32**
1¼" Basic Camera adapter, 2 part system	**$32**
0.96" Basic Camera adapter, 2 part system	**$32**
1¼" prime Focus adapter, fits 1¼" focuser	**$22**
0.96" prime Focus adapter, fits 0.96" focuser	**$22**
Camera T-ring, specify 35mm camera type	**$12**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

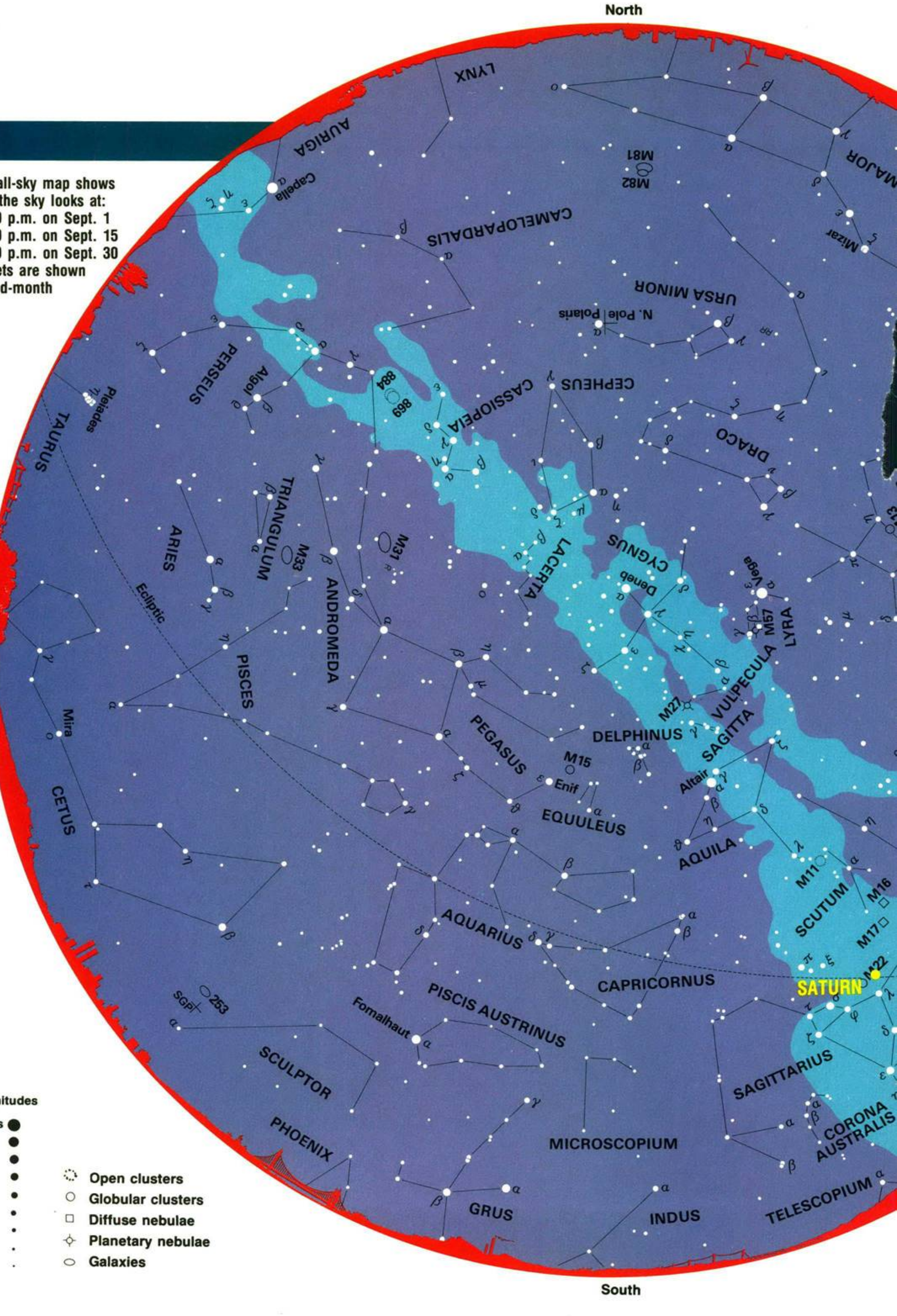
1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle version, w/star diagonal	**$195**
2" right-angle version, non-rotating focuser*	**$199**
1¼" Deluxe right-angle Super-Finder*	**$279**
2" Deluxe right-angle Super-Finder*	**$309**
25mm Cross-hair 1¼" eyepiece (12X)	**$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver,	**$159**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**

The all-sky map shows
how the sky looks at:
11:30 p.m. on Sept. 1
10:30 p.m. on Sept. 15
9:30 p.m. on Sept. 30
Planets are shown
at mid-month


North
South
East
LYNX
AURIGA
Capella
M81
M82
CAMELOPARDALIS
URSA MINOR
N. Pole Polaris
MAJOR
Mizar
PERSEUS
Algol
Pleiades
TAURUS
884
869
CASSIOPEIA
CEPHEUS
DRACO
TRIANGULUM
ARIES
M33
M31
ANDROMEDA
LACERTA
CYGNUS
Deneb
Vega
M57
LYRA
Ecliptic
PISCES
VULPECULA
M27
SAGITTA
DELPHINUS
Mira
PEGASUS
M15
Enif
EQUULEUS
Altair
AQUILA
CETUS
M11
SCUTUM
M16
M17
AQUARIUS
CAPRICORNUS
SATURN
M22
SGP
253
PISCIS AUSTRINUS
Fomalhaut
SAGITTARIUS
SCULPTOR
CORONA AUSTRALIS
PHOENIX
MICROSCOPIUM
GRUS
INDUS
TELESCOPIUM

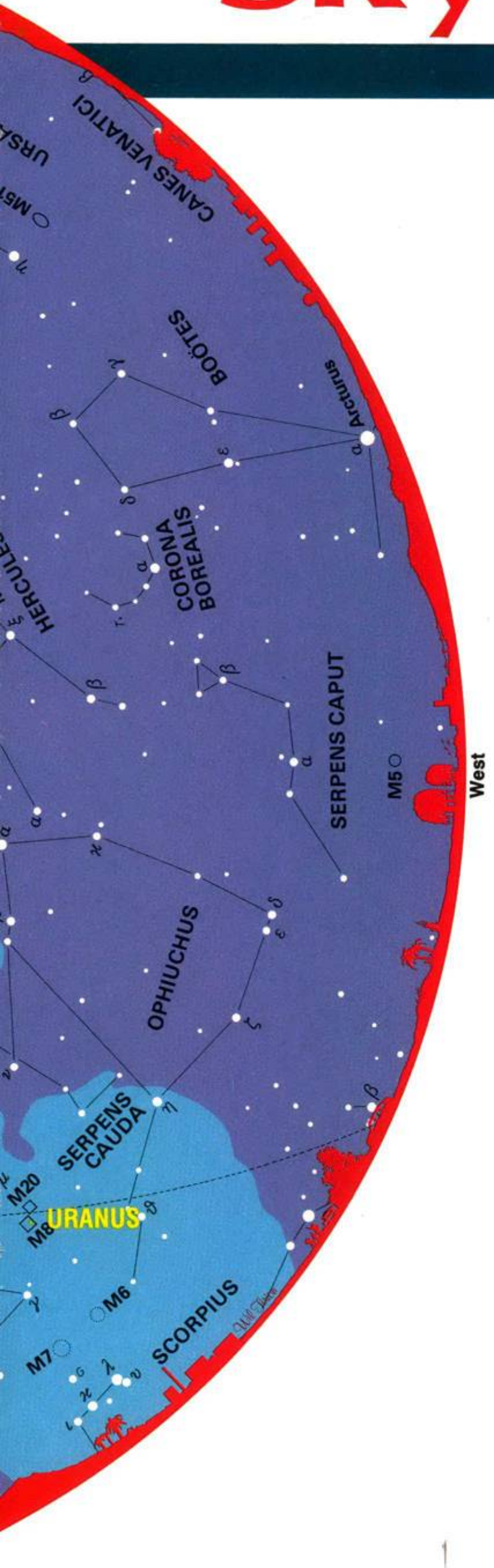
Magnitudes

- Sirius ●
- 0.0 ●
- 0.8 ●
- 1.6 ●
- 2.4 •
- 3.2 •
- 4.0 •
- 4.8 ·
- 5.6 ·

- ⁙ Open clusters
- ○ Globular clusters
- □ Diffuse nebulae
- ✧ Planetary nebulae
- ⬭ Galaxies

Sky Almanac

SEPTEMBER 1989



RETURN OF A BRIGHT COMET

The brightest periodic comet in three years puts on its best show this month. Look for Comet Brorsen-Metcalf before dawn during the first ten days and again during the last week of September. At its brightest, the comet should be visible to the naked eye.

A MOON TO HARVEST BY

September's Full Moon is better known as the Harvest Moon. The nearly Full Moon dominates the early evening sky for several days around the 15th and rises thirty minutes later each night.

TAU SCORPII COVERED BY THE MOON

On the evening of September 7, observers in much of the northern United States and Canada can see the First Quarter Moon occult Tau Scorpii, a 2.9-magnitude star just south of Antares.

TWO CLOSE APPROACHES FOR VESTA

This is a busy month for the 7th-magnitude asteroid Vesta. On the night of September 5/6 it passes 2° south of Uranus, then it passes 37′ south of Lambda Sagittarii on the night of September 24/25.

Dates and Times

2 The Moon passes 0.6° south of Mercury, noon EDT

3 The Moon passes 5° south of Venus, 5 p.m. EDT

4 The Moon is at apogee (252,111 miles from Earth), 4:26 a.m. EDT

5 Pluto is at perihelion (2.76 billion miles from the Sun)

6 Venus passes 1.9° north of Spica, 9 a.m. EDT

7 The Moon passes 0.6° south of Antares, 6 p.m. EDT

8 First Quarter Moon is at 5:49 a.m. EDT

9 The Moon passes 4° south of Saturn, 10 p.m. EDT

11 Saturn is stationary

12 Parthenope is at opposition

15 Full Moon is at 7:51 a.m. EDT

16 The Moon is at perigee (223,101 miles from Earth), 11:19 a.m. EDT

21 Last Quarter Moon is at 10:10 p.m. EDT

22 The Moon passes 4° north of Jupiter, 3 p.m. EDT
Autumnal equinox is at 9:20 p.m. EDT

24 Mercury is in inferior conjunction

26 The Moon passes 1.0° south of Regulus, 5 p.m. EDT

27 Comet Brorsen-Metcalf is at perihelion

29 Mars is in conjunction with the Sun
New Moon is at 5:47 p.m. EDT

30 Pallas is at opposition

Eye on the Sky by Deborah Byrd

1989'S BRIGHTEST COMET

The best periodic comet of 1989 should become bright enough to see with the naked eye this month. This year, Comet Brorsen-Metcalf makes its first predicted return to the inner solar system. Discovered by German astronomer Theodor Brorsen in 1847 and accidentally recovered in 1919 by American comet-hunter Joel Metcalf, the comet follows a 70.6-year orbit quite similar to that of Comet Halley.

The best times to look for Comet Brorsen-Metcalf are the predawn hours during the first ten days of September and the last week of September, when the Moon is out of the sky. At the beginning of the month, Brorsen-Metcalf lies in the relatively faint constellation Lynx and appears about 35° above the northeastern horizon at the beginning of morning twilight. (See Through the Eyepiece for the comet's position during this period.) The comet is expected to shine at roughly 6th magnitude, so it may be visible to the naked eye under a very dark sky. By the end of the month, the comet moves into Leo and should lie approximately 15° above the eastern horizon at the beginning of twilight (see map below). Astronomers predict the comet will shine brightest then — at about 5th magnitude — but its position closer to the horizon may make it more difficult to spot.

Faint comets are elusive objects, and you'll probably have to hunt a bit to see this one. A pair of binoculars is an immense help because their greater light-gathering power can make a relatively faint comet appear distinct against the background sky. Do your best to avoid looking for the comet from a site near city lights: the sky glow will wash out the comet's diffuse glow.

THE SUN SINKS SOUTHWARD

At 9:20 p.m. EDT on September 22, the center of the Sun crosses the celestial equator, an imaginary line that is the projection of Earth's equator into the sky. This event marks the equinox, the official beginning of autumn in the Northern Hemisphere and spring in the Southern Hemisphere.

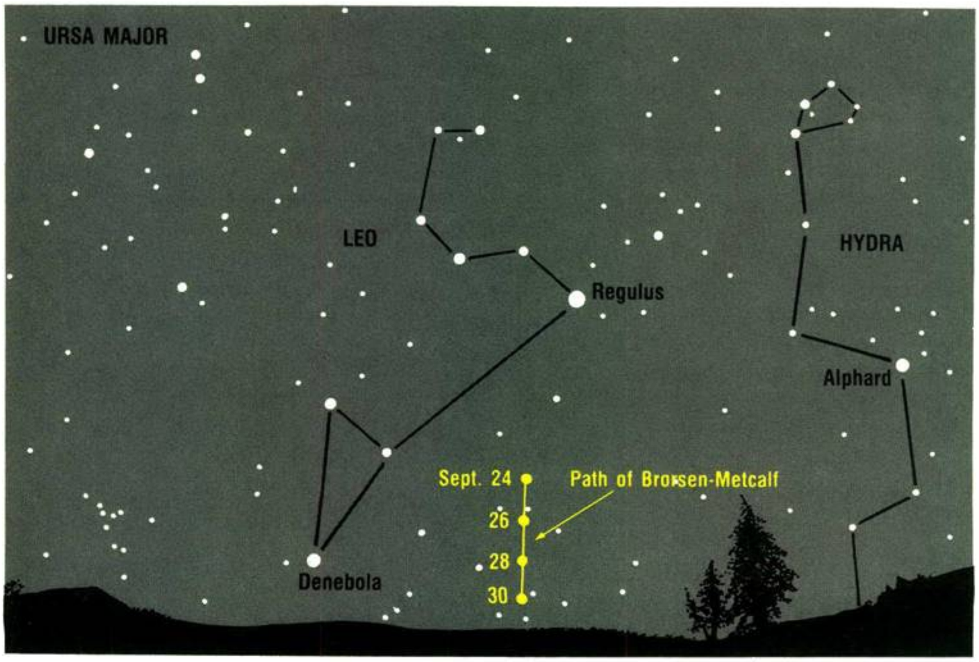
Ever since the June solstice (June 21), the Sun's daily path across the sky has been edging southward. This southerly motion continues until the winter solstice (December 21), but the movement is fastest at the equinox. If you track the Sun's height at around noon a few weeks before and after the equinox, you can see the midday Sun edge closer to the southern horizon.

BY THE LIGHT OF THE HARVEST MOON

People have come to call the Full Moons seen throughout the year many names, but — with the possible exception of the Blue Moon — none is so famous as the Harvest Moon. This is the Full Moon you'll see illuminating the sky on the night of September 14/15.

Most Full Moon names (again with the exception of the Blue Moon) are tied to particular months. For example, the Fruit Moon is the name given to September's Full Moon. The Harvest Moon, on the other hand, is not tied to a month, but to the September equinox. The Harvest Moon is the Full Moon nearest

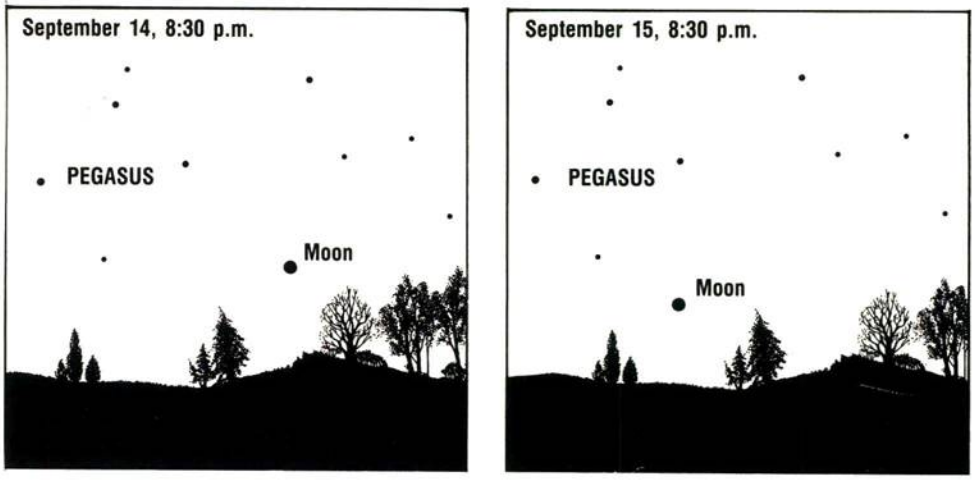
COMET BRORSEN-METCALF should be visible to the naked eye in the eastern predawn sky during the last week of September.



this equinox, so it occasionally falls in October.

Unless you're inclined toward romance, in which case any moonlit night will do, the Harvest Moon is the year's most functional Full Moon. Before the era of tractor lights, farmers bringing in their crops could work without interruption under the silvery light of this early autumn Full Moon.

The Harvest Moon's usefulness arises from the special circumstances at moonrise this time of year. Around the time of the equinox, the ecliptic — an invisible path across the sky followed closely by the Sun, Moon, and planets — makes a shallow angle with the eastern horizon in early evening. From one day to the next, the Moon moves eastward along the ecliptic as it moves in orbit around Earth. At most other times of the year, this eastward motion causes the Moon to rise about fifty minutes later each day. At this time of year, however, the ecliptic's shallow angle relative to the horizon means that each succeeding day the Moon has a shorter distance to travel before rising than it usually does. Thus the nearly Full Moon appears over the eastern horizon only about thirty minutes later each evening for several days in a row and there is no long period of darkness between sunset and moonrise.


September 14, 8:30 p.m.

September 15, 8:30 p.m.

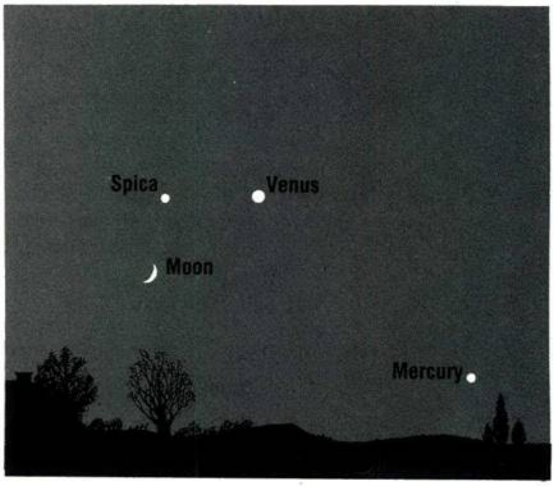
THE HARVEST MOON RISES only thirty minutes later each succeeding night and its altitude changes little from one evening to the next. For example, the Moon lies just 5° lower on September 15 than it does on the 14th.

SEPTEMBER'S PLANETS

Mercury hovers low in the west after sunset in early September. The planet's greatest elongation was on August 29, but even then the shallow angle of the ecliptic to the horizon made Mercury difficult to see. On September 1, 0.3-magnitude Mercury sets about an hour after the Sun, but you'll probably have to search with binoculars to see it. Mercury passes between the Sun and Earth on September 24 and reappears in the morning sky in October.

The brilliant "evening star" low in the west-southwest after sunset is Venus. Venus lies near the star Spica in Virgo when the month begins and passes 1.9° north of the star on September 6. Although closest approach occurs around dawn for North American observers, when the pair is below the horizon, the two objects remain close for several evenings.

A CRESCENT MOON JOINS Venus and 1st-magnitude Spica on September 3. Look for the tight trio low in the west-southwest thirty minutes after sunset.



Venus shines at magnitude −4.1 this month, more than one hundred times brighter than magnitude 1.0 Spica. And Venus will grow even brighter in the months ahead. It is rapidly catching up to Earth as it races around the Sun in its smaller, faster orbit. During September, it pulls nearly 20 million miles closer.

Saturn comes into view low in the south as darkness falls. It shines at magnitude 0.4 this month, a shining point near the top of the "Teapot" asterism in Sagittarius.

This planet was more conspicuous last summer, shining brightly throughout most of the night amidst the stars of the summer Milky Way. Saturn was at opposition, directly opposite the Sun in our sky, in early July and at that point was moving westward with respect to the stars.

Normally, the outer planets move toward the east in front of the stars. A few months before opposition, however, their eastward motion slows to a crawl and then stops. Then, like retreating soldiers, they start moving the opposite way. This westward, or retrograde, motion of the planets boggled the minds of the world's greatest thinkers for centuries. It happens because as we zoom between an outer planet and the Sun, our motion to the west is faster than that of the outer planet. It's as though we're riding along a great highway in a sleek sports car. As we pass slower cars, we see them appear to move backward for a time against the distant landscape. Likewise, outer planets appear to move backward against the distant "starscape" as Earth passes between them and the Sun.

Saturn ends its retrograde motion on the night of September 10/11 and then resumes its eastward motion. Because Saturn is the outermost planet easily visible to the naked eye, its motion is slower than the other planets. It will appear to move very little with respect to its neighboring stars over the next few months.

About 6° west and 1° south of Saturn lies Uranus. It is a 5.7-magnitude point of light best seen with binoculars. On September 1 Uranus reaches its southernmost point in our sky since 1905 and then begins a long, 42-year journey northward.

Jupiter, located in the constellation Gemini, rises around midnight this month. It appears high in the east-southeast at dawn, a bold light shining at magnitude −2.2. The bright planet is easily the most conspicuous point of light visible in the after-midnight hours. Jupiter will become even more conspicuous in the coming months, as it grows brighter and rises earlier on its way to opposition in December.

Mars is on the far side of the Sun this month and is not visible at all. The Red Planet reaches conjunction with the Sun on September 29, but it does not return to the morning sky until November.

SEPTEMBER'S STARRY SKY

If you happen to have a particularly clear western sky in late afternoon, you should watch for one of the most elusive sights in naked-eye astronomy. The green flash appears as a flash of green light as the Sun's upper limb disappears behind the horizon.

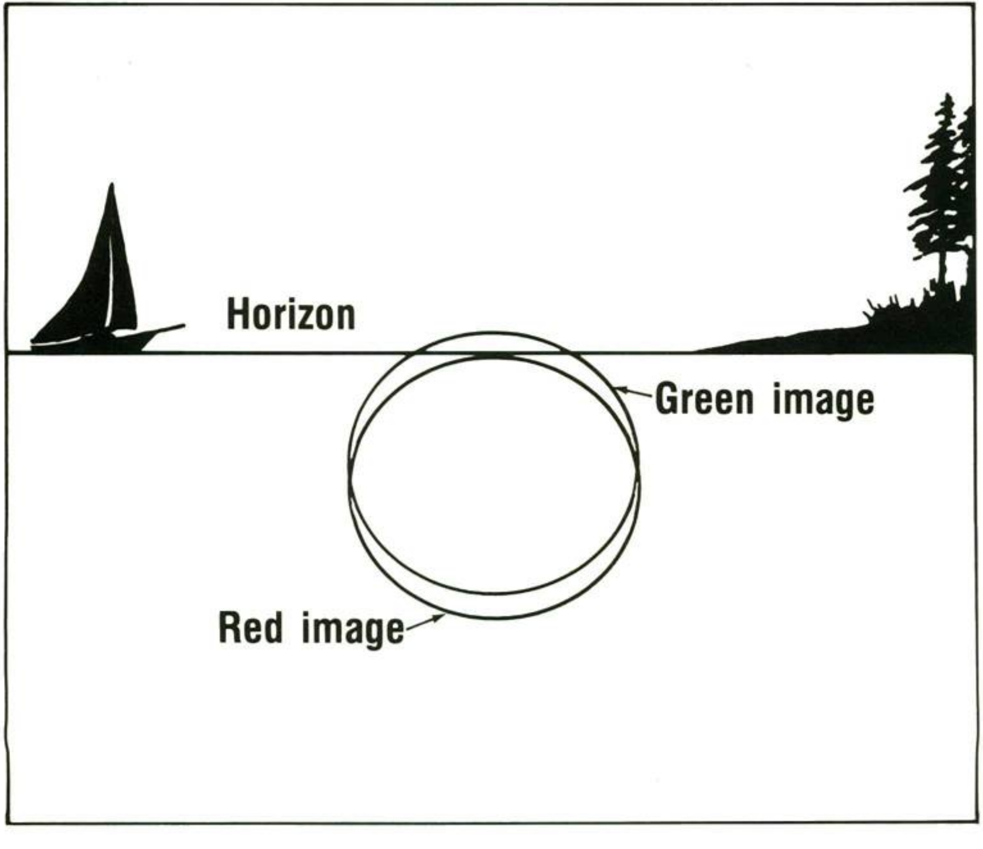
You'll have to be persistent to see a green flash because sky conditions have to be just right. You definitely need a clear western sky that is free of dust and clouds. A sea horizon is probably best for seeing the green flash, but any flat, far horizon will do.

Although I've seen the green flash through binoculars, I have yet to see it with the naked eye. If you want to watch for it with optical aid, however, be *extremely* careful not to look at the Sun until the last possible moment. Otherwise, you can severely damage your eyes, ending your stargazing days permanently.

Astronomers think that the green flash occurs because much of the Sun's light is scattered or absorbed by Earth's atmosphere when the Sun is low in the sky. The blue light is lost and what's left — the red and green components of sunlight — is refracted, or bent, by the atmosphere.

It so happens that the red light is bent less than the green light. In essence, we see two solar disks of different colors, with the red one slightly below the green one. On very clear evenings, when the sunset is viewed across a great distance, you can witness the red disk slipping below the horizon moments before the green one: the green flash! ☐

THE LAST RAY of the setting Sun may flash green on very clear evenings. This "green flash" arises from refraction in Earth's atmosphere, which causes the red image of the Sun to dip below the horizon before the green image does.



Through the Eyepiece by Rick Shaffer

THE RETURN OF COMET BRORSEN-METCALF

During the dark of the Moon every month this past winter and spring, astronomers sought the long-awaited Comet Brorsen-Metcalf. As of mid-June, however, the comet had eluded all attempts at recovery. Astronomers still expect Brorsen-Metcalf to put on a good show at this, its third known apparition. However, there is enough uncertainty in predictions of the comet's behavior that backyard observers should follow the comet's progress closely.

Comet Brorsen-Metcalf should be moderately bright and well-placed in the morning sky during most of September. At the beginning of the month, the approximately 7th-magnitude comet lies in Lynx and is 35° above the northeastern horizon when morning twilight begins. Over the next ten days — the first of two Moon-free observing windows this month — the comet should brighten to 6th magnitude and move from Lynx, through Leo Minor, and into Leo.

The second good observing period occurs when the Moon passes out of the morning sky during the last week of September. Located approximately halfway between Leo's two brightest stars, Regulus and Denebola, the comet lies some 15° above the eastern horizon as morning twilight begins. Brorsen-Metcalf should peak in brightness at around 5th magnitude a few days before it reaches perihelion on September 27/28.

The reason astronomers have had such a hard time recovering Comet Brorsen-Metcalf is revealed in the comet's observational history. Astronomer Theodor Brorsen discovered the comet on July 20, 1847, from the Altona Observatory in Germany. Comet Brorsen shone at magnitude 9.5 and appeared quite diffuse with no discernible nucleus. It reached maximum brilliance, magnitude 6.5, in mid-August, and its tail measured a scant 15′ long.

Because the comet lacked an observable nucleus, observers had a difficult time estimating the center of the fuzzy blob in their field of view. These inexact measurements, coupled with the fact that the comet was observed for a total of only 56 days, led to inaccuracies in calculating the comet's period.

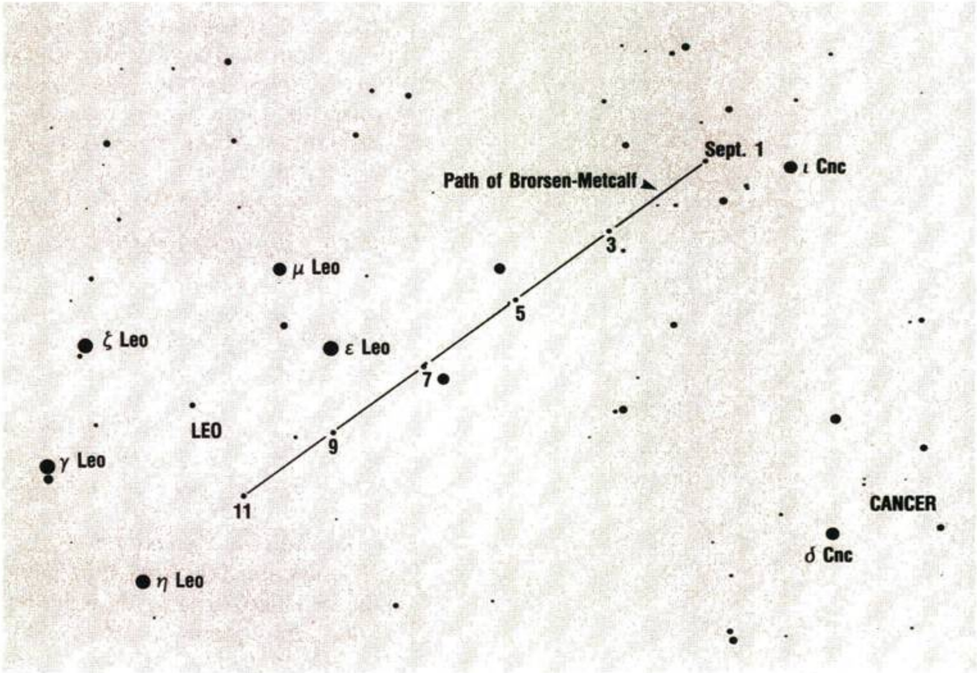
On August 21, 1919, two years before the predicted return of Comet Brorsen, the Reverend Joel Metcalf discovered a comet with a 7-inch refractor from Vermont. The orbit calculated for Metcalf's comet was identical to that of Comet Brorsen, and because he had independently discovered it, Metcalf's name was added to the comet's previous name.

During the 1919 apparition, Comet Brorsen-Metcalf reached a peak magnitude of 4.5 and its tail reached a length of 1.5° visually and several degrees photographically. Significantly, no observer reported seeing a well-defined nucleus at this apparition either.

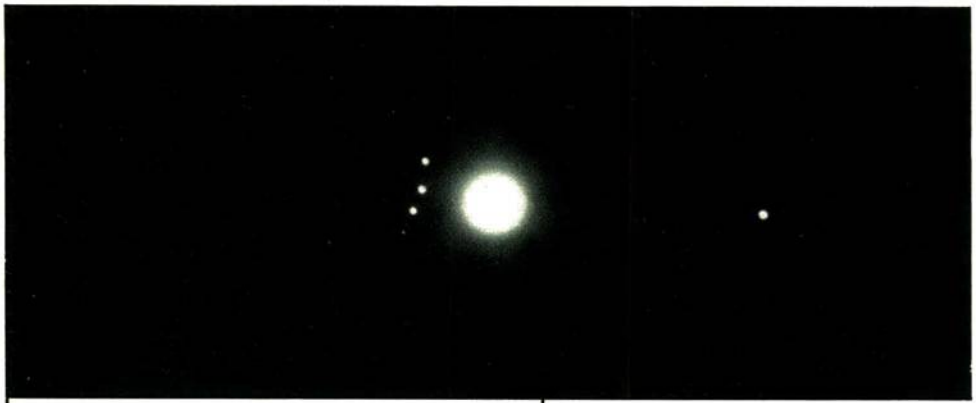
The two previous apparitions show why it has taken astronomers so long to recover Brorsen-Metcalf this time around. First, although the comet's orbit is reasonably well known, Brorsen-Metcalf may be a bit off the predicted path. Second, because the comet is very diffuse, its light is spread out over a large area, so its apparent brightness may not have been significantly

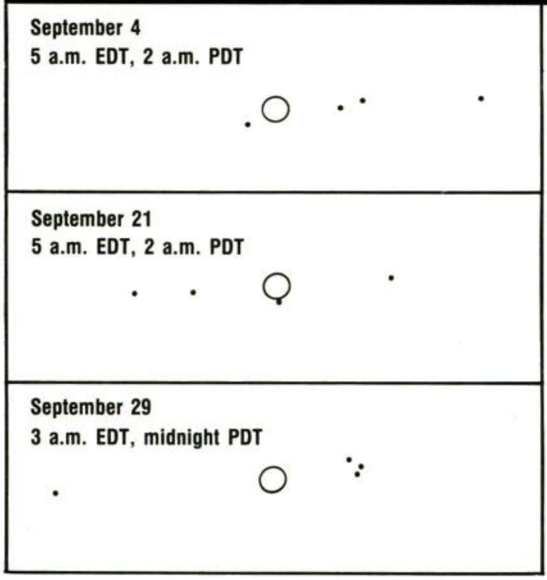
COORDINATES FOR COMET BRORSEN-METCALF

Date	R.A. (2000)	Dec.
Sept. 1	8h57.7m	29°07′
Sept. 4	9h16.8m	26°15′
Sept. 7	9h34.3m	23°20′
Sept. 10	9h50.7m	20°24′
Sept. 13	10h06.2m	17°28′
Sept. 16	10h21.0m	14°34′
Sept. 19	10h35.0m	11°45′
Sept. 22	10h48.4m	9°02′
Sept. 25	11h01.1m	6°26′
Sept. 28	11h13.2m	3°59′
Oct. 1	11h24.6m	1°41′



THE BRIGHTEST COMET of 1989, Comet Brorsen-Metcalf, should put on an excellent show during early September. Look for the comet in the northeast before morning twilight. (Positions are given for 6 a.m. EDT, 3 a.m. PDT.)





JUPITER'S GALILEAN SATELLITES do not always appear in a straight line. North American observers can see this unusual configuration three times this month. Photo taken by Dirk Terrell and Daniel Durda on November 15, 1988.

greater than the brightness of the background sky against which it had to be observed.

The diffuseness of the coma means that, even if the comet reaches 5th magnitude as predicted, the light will probably be spread over a fairly large area of the sky and not concentrated into an observable nucleus. There are several things you can do to overcome this problem.

First, pick an observing site that is free from stray light and darkest toward the east and northeast.

Second, you should observe on nights when the sky is very transparent. In addition to a transparent sky, your optics must also be transparent — keep the optics clean and don't let dew fog your view.

Third, give your eyes at least half an hour to adapt to the dark before attempting to find the comet. If you wake up early to view the comet, don't turn on any bright lights.

Finally, to assure the highest possible image contrast between the comet and the background sky, you should observe with the lowest magnification eyepiece possible. However, don't pick an eyepiece that gives an exit pupil greater than 7 millimeters, or your dark-adapted eyes won't be able to gather all the light the eyepiece provides. You might want to try 10x70 or 11x80 binoculars to get a good first view of Brorsen-Metcalf.

If you don't spot Brorsen-Metcalf right away, don't despair. Try using averted vision. Instead of looking directly at the predicted position, look toward the edge of the field of view. This utilizes the area of your retina most sensitive to faint light. If this technique fails, gently tap your telescope tube or move the binoculars back-and-forth as you look at the comet's predicted position. The eye sees dim objects more readily when they are moving slightly.

THE MOON BLOCKS TAU SCORPII

The First Quarter Moon passes in front of the 2.9-magnitude star Tau (τ) Scorpii on the evening of September 7. Because the Moon is waxing, the star disappears behind the unlit part of the Moon, which makes the event much easier to view, and reappears from behind the bright limb.

Observers along a line beginning near Montreal and running southwest into south-central New Mexico can see the star skirt the southern limb of the Moon. Observers north of this line can see Tau disappear completely behind the Moon. The times at which the star disappears and reappears are given in the table on page 63 for several cities.

VESTA PASSES CLOSE TO URANUS

On the night of September 5/6, asteroid 4 Vesta passes 2° south of Uranus. Although Vesta has faded from 5th to 7th magnitude over the last two to three months, it is still easy to pick out with binoculars or a telescope. Uranus shines a magnitude brighter than Vesta and sports a blue-green disk 3.7″ across.

Vesta has an even closer encounter later in the month. On September 24 Vesta passes 37′ south of the star Lambda (λ) Sagittarii. This star marks the top of the "Teapot" asterism in Sagittarius.

TELESCOPIC PLANETS

Mercury spends most of September lost in the Sun's glare. You might glimpse the 8″-diameter, half-lit disk of the elusive planet in the first few days of the month. Look low in the west about thirty minutes after sunset.

Although it is also low in the twilight after sunset, Venus is much easier to see than Mercury because it is so much brighter, shining at magnitude −4.1. Venus' disk grows from 14″ to 17″ across during September, while the illuminated portion of its disk shrinks from 76 percent to 66 percent. Because Venus remains low in the west-southwest this month, lying just 10° high thirty minutes after sunset, you won't get a crisp view of the solar system's brightest planet.

The Red Planet is not visible during the month of September. Currently positioned on the opposite side of the Sun from Earth, Mars will not reappear until mid-November, when it will be low in the eastern predawn sky.

Observing Jupiter gets easier as September progresses. The largest of the planets rises around midnight at the middle of the month and is high in the south when morning twilight begins. You should have little problem seeing the bright zones and dark belts circling Jupiter's 37″-diameter disk using medium to high magnifications.

Just as interesting as the atmospheric features are Jupiter's four Galilean satellites. Io, Europa, Ganymede, and Callisto orbit in the equatorial plane of Jupiter. From Earth they normally appear in a straight line on either side of Jupiter. However, when the planet's equator is tilted a few degrees to our line of sight, one or more of the moons may appear out of line. The diagrams at the top of page 62 show the best times this month to look for this unusual sight.

The three outer gas giants — Saturn, Uranus, and Neptune — are now fairly high in the south as the sky darkens after sunset. By far the most interesting of the three is Saturn. The ringed planet measures 17″ across this month and its rings span 39″. Although Saturn possesses alternating atmospheric bands similar to those on Jupiter, they are much more subtle and difficult to see.

The highlight of Uranus' month is its close approach to Vesta on September 4/5. Throughout September the planet can be found approximately 6° west and 1° south of Saturn. Neptune remains close to Saturn this month. The 7.9-magnitude planet lies just 2.5° east and 0.5° north of the ringed planet. Neptune appears as a featureless, blue-gray disk measuring 2.2″ across.

On September 5 Pluto reaches its first perihelion since it was discovered in 1930. Still, at 29.656 astronomical units (about 2.76 billion miles) from the Sun, Pluto is an exceedingly difficult object to find. You'll need an 8-inch or larger telescope and exceptional sky conditions to glimpse the remote planet. Use the finder chart on page 85 of the January issue to find Pluto's general location, then make a detailed sketch of the region down to at least 14th magnitude. If you do this a day or two before the 5th and then compare the drawing to the same field on the 5th, the "star" that changed position is Pluto. If you're an aficionado of obscure yet momentous events, savor this one — Pluto will not reach perihelion again until the year 2236.

ASTEROIDS IN THE EYEPIECE

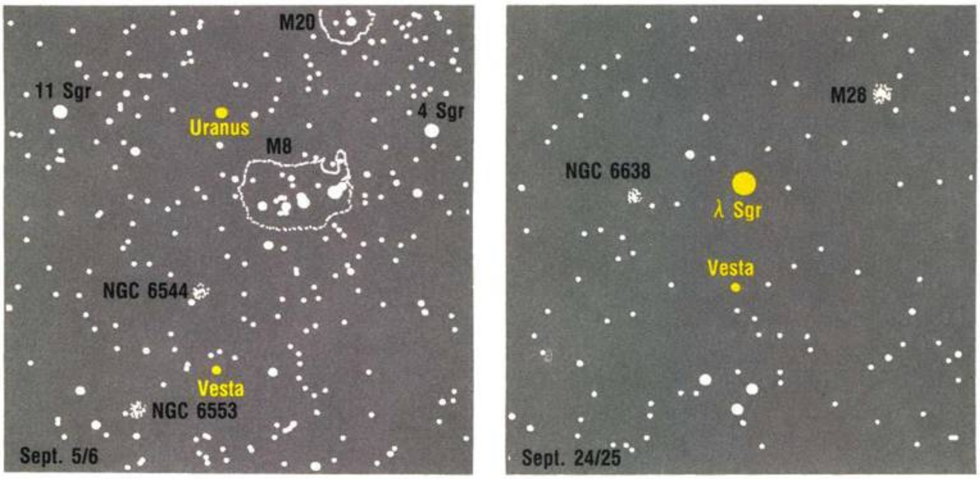
Besides Vesta's close approaches to Uranus and Lambda Sagittarii, two other asteroids merit attention this month. The second largest and third brightest asteroid, 2 Pallas, reaches opposition on September 30. The 8th-magnitude point of light lies in Cetus throughout September. Also, asteroid 11 Parthenope reaches a favorable opposition on September 12. Parthenope lies in Aquarius and shines at magnitude 9.1. □

OCCULTATION OF TAU SCORPII

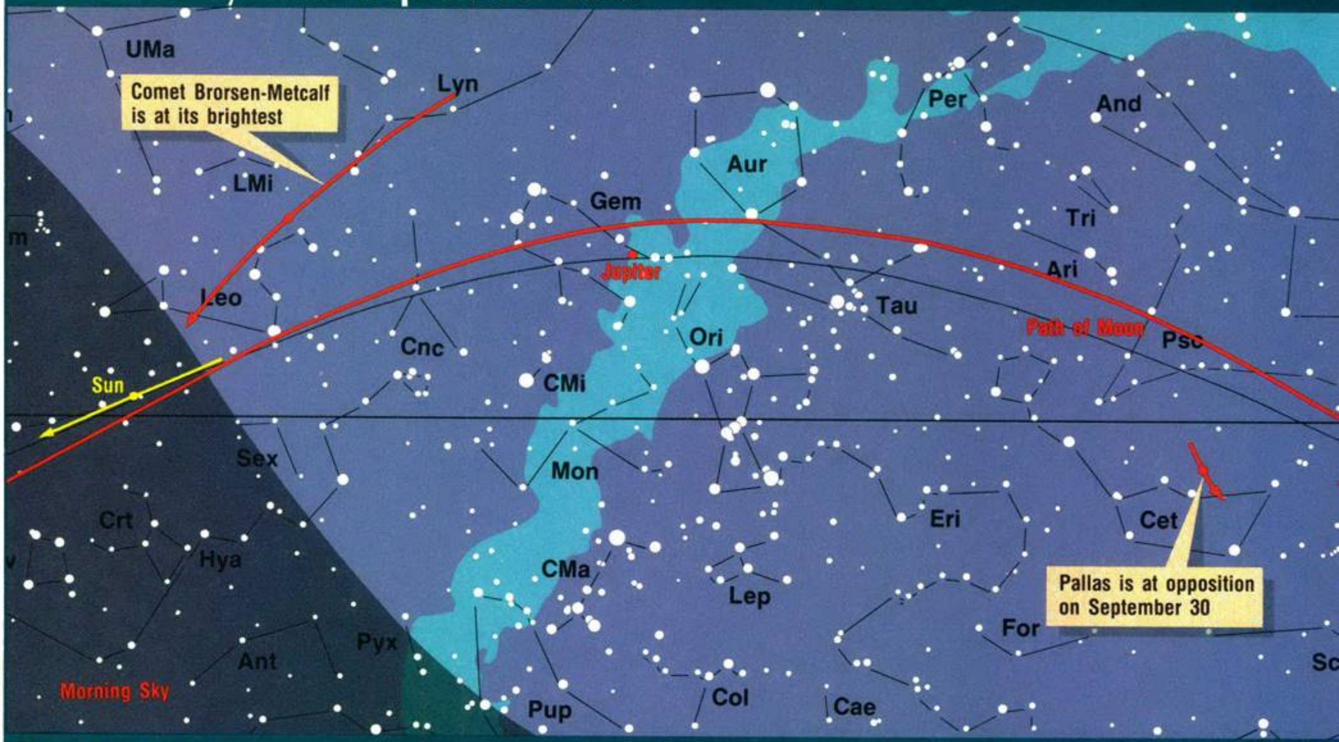
City	Disappears	Reappears
Chicago	8:24 CDT	9:02 CDT
Denver	6:50 MDT	7:40 MDT
Edmonton	6:26 MDT	7:27 MDT
Kansas City, MO	8:15 CDT	8:55 CDT
Seattle	5:19 PDT	6:06 PDT
Toronto	9:41 EDT	—
Vancouver	5:18 PDT	6:06 PDT
Winnipeg	7:51 CDT	8:52 CDT

On the evening of September 7, Tau Scorpii disappears and reappears from behind the Moon at the times shown. A dash indicates that the event is not visible.

VESTA PASSES CLOSE to two noteworthy objects this month. The 7th-magnitude asteroid lies 2° south of Uranus on September 5/6 and 37′ south of the star Lambda Sagittarii on September 24/25.



The Solar System September 1989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Pyx
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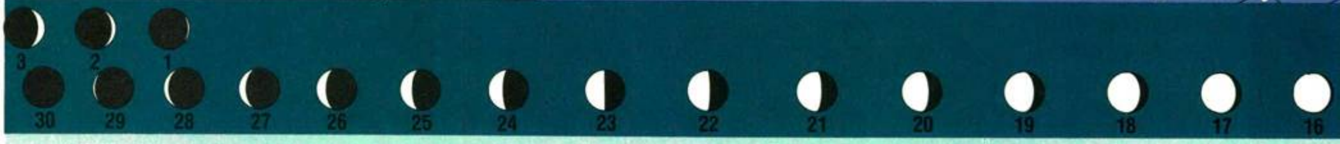
Comet Brorsen-Metcalf is at its brightest

Pallas is at opposition on September 30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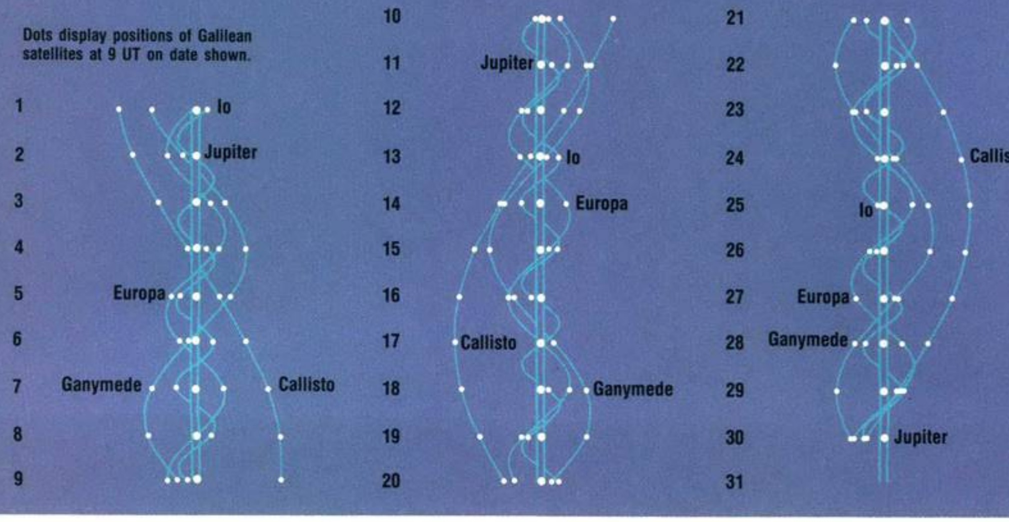
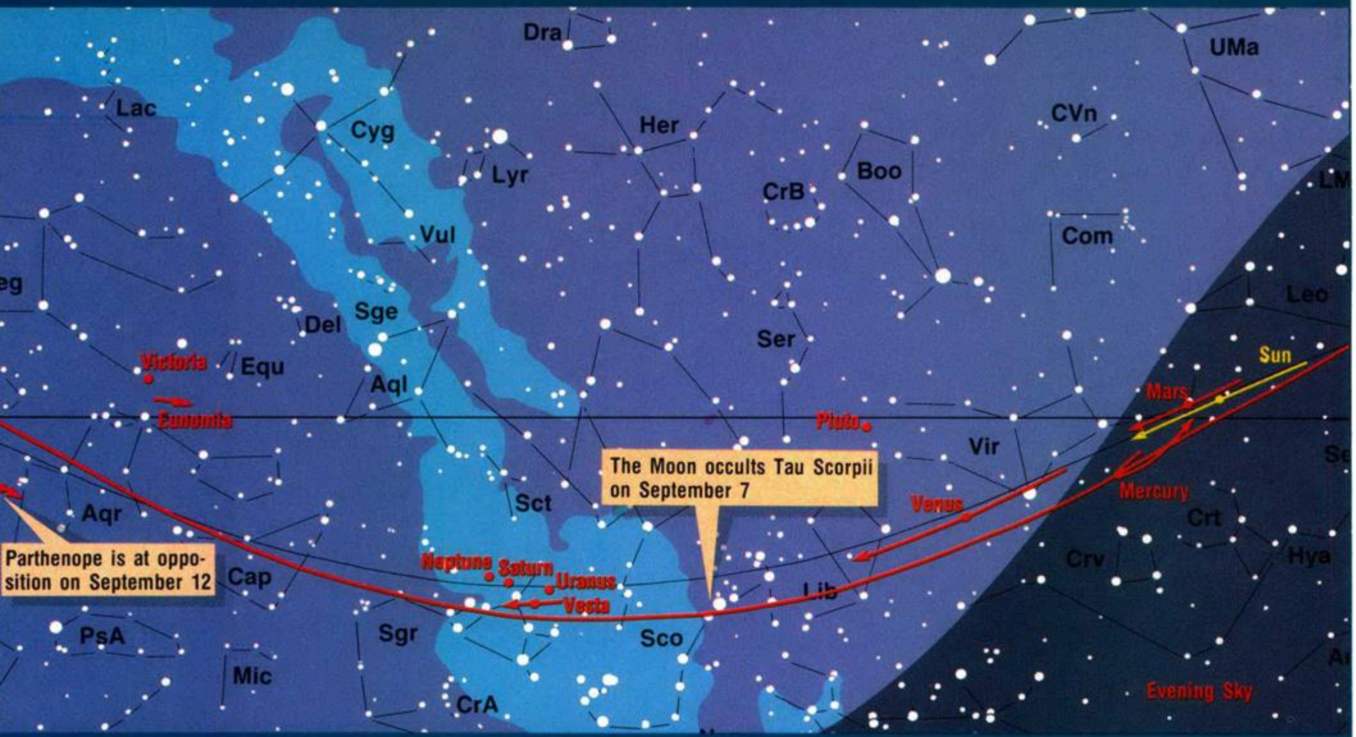
Planet	MERCURY	MERCURY	VENUS	MARS
Date	Sept. 1	Sept. 30	Sept. 15	Sept. 15
Magnitude	+0.3	+2.6	−4.1	+1.7
Angular Size	7.52″	9.50″	15.5″	3.5″
Illumination	50%	7%	72%	100%
Distance (AU) from Earth	0.894	0.708	1.074	2.651
Distance (AU) from Sun	0.460	0.327	0.727	1.651
Right Ascension (2000.0)	12h16.6m	11h48.1m	14h02.1m	11h51.0m
Declination (2000.0)	−4°43′	0°05′	−13°18′	1°56′

Jupiter's Moons

Dots display positions of Galilean satellites at 9 UT on date shown.

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Aql
Mars
Eunomia
Pluto
Vir
Se
Sct
Venus
Mercury
Aqr
Crt
Hya
Cap
Neptune
Saturn
Uranus
Crv
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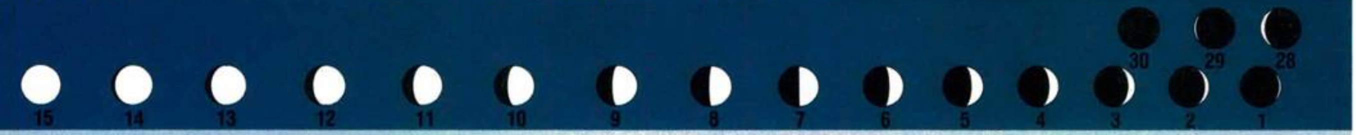
Evening Sky

The Moon occults Tau Scorpii on September 7

Parthenope is at opposition on September 12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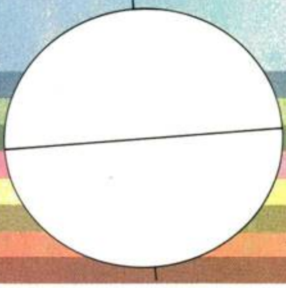
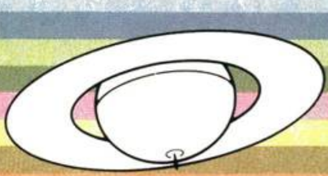
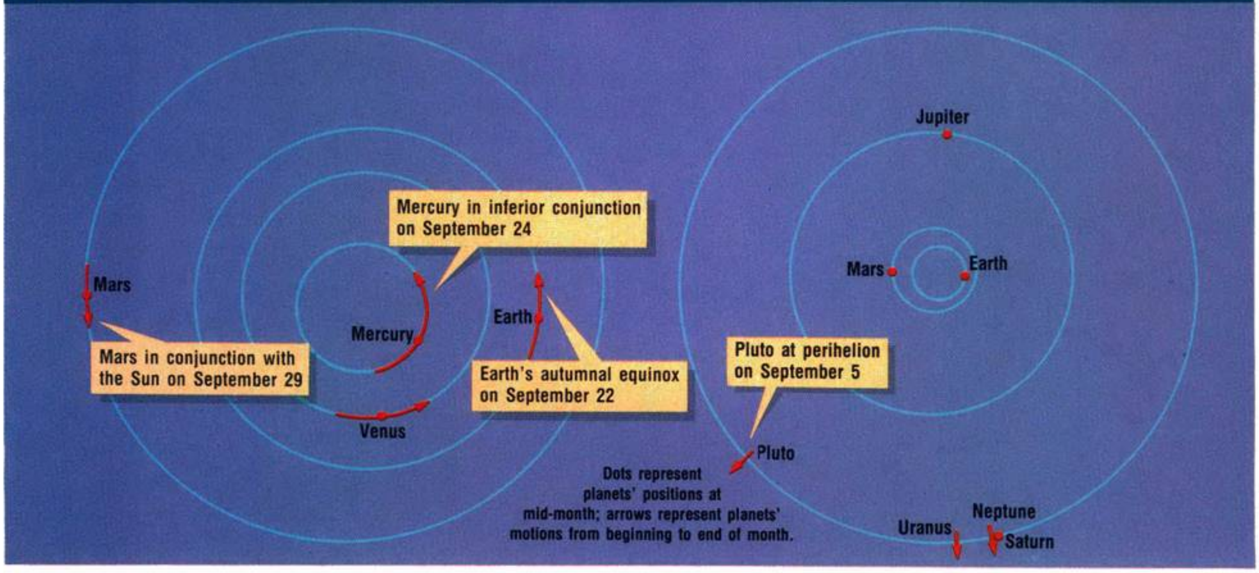




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Sept. 15	Sept. 15	Sept. 15	Sept. 15	Sept. 15
−2.2	+0.4	+5.7	+7.9	+13.8
37.2″	17.0″	3.7″	2.2″	0.1″
99%	100%	100%	100%	100%
5.293	9.724	19.174	29.896	30.255
5.113	10.034	19.361	30.213	29.656
6h34.8m	18h32.3m	18h06.5m	18h42.2m	15h01.7m
22°54′	−22°45′	−23°42′	−22°11′	−1°10′

The Planets in Their Orbits


Mars
Mercury
Earth
Venus
Jupiter
Mars
Earth
Pluto
Uranus
Neptune
Saturn

Mercury in inferior conjunction on September 24

Mars in conjunction with the Sun on September 29

Earth's autumnal equinox on September 22

Pluto at perihelion on September 5

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

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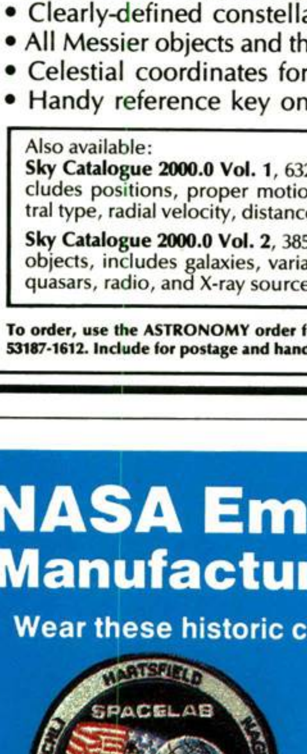
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SPACELAB
BUCHLI
NAGEL
D1
MESSERSCHMID
BLUFORD
OCKELS
DUNBAR
FURRER

STS 61A
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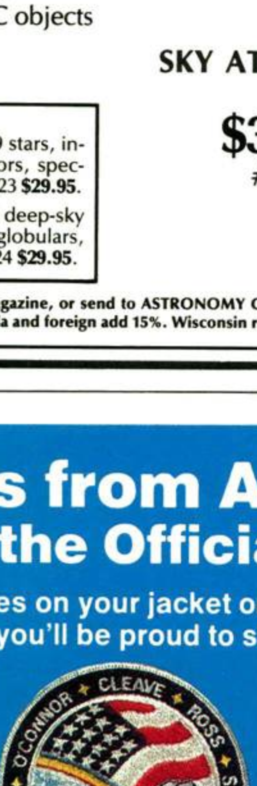
CLEAVE
ROSS
SPRING
O'CONNOR
SHAW
WALKER
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STS 61B
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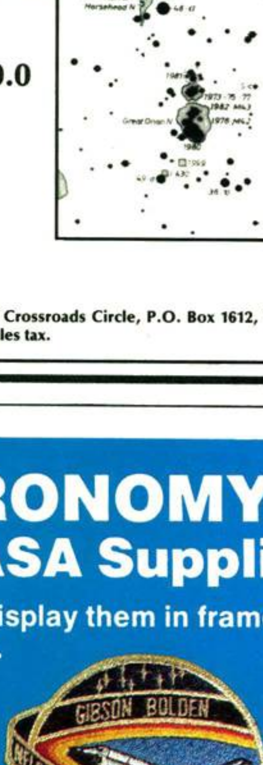
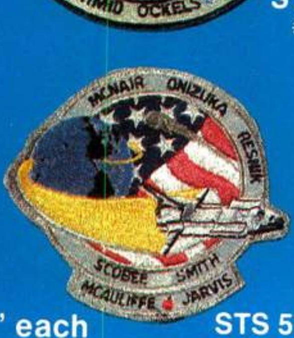

GIBSON BOLDEN
NELSON HAWLEY CHANG-DIAZ
CENKER NELSON

STS 61C
#35075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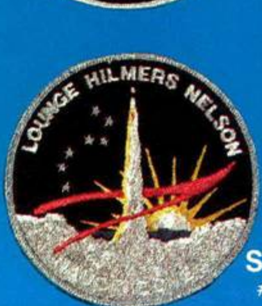
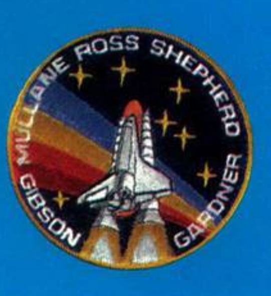

LOUNGE
HILMERS
NELSON

STS 26
#35077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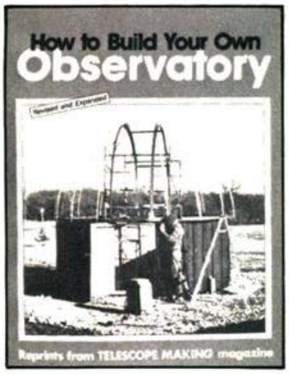

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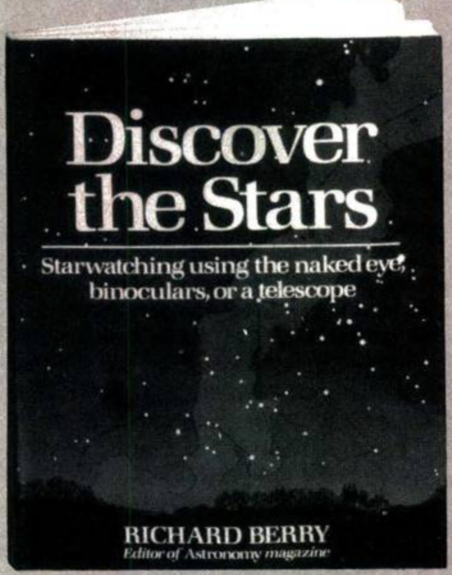

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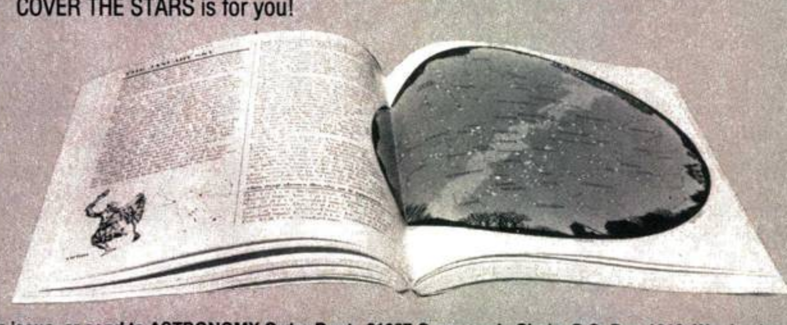

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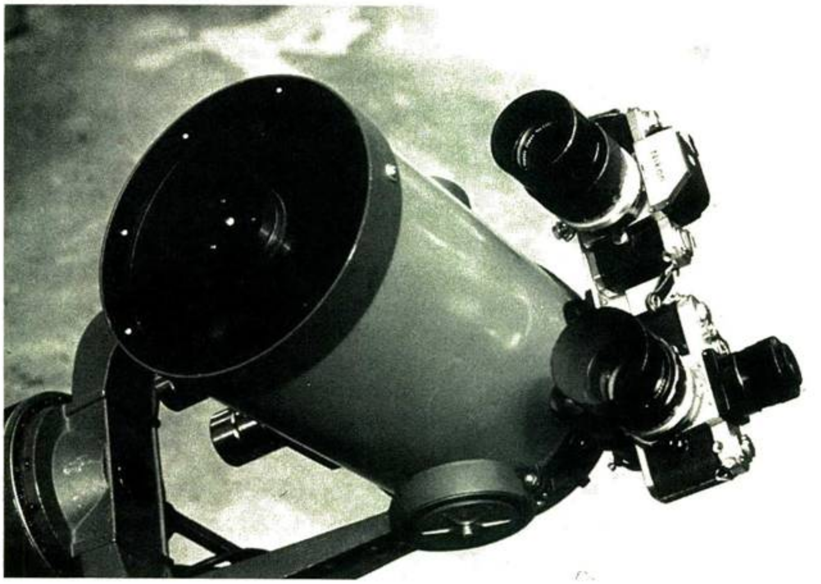
Astrophotos the Easy Way

If you thought astrophotography was beyond your budget and abilities, try piggybacking your camera on your telescope.

by Robert Reeves



PIGGYBACKING A CAMERA is easy if you have an equatorially mounted telescope. Using two cameras at once lets you test different films or lenses — or shoot separate objects.

Piggyback astrophotography is almost the easiest and cheapest type of photography for amateur astronomers. You attach your camera and lens to a telescope, point the camera at the sky, and shoot while tracking a star. (The only simpler method is aiming your camera skyward from a tripod to record star trails.) Besides a camera and lens, the most important piece of equipment for piggybacking is an equatorially mounted telescope.

I use an 8-inch Schmidt-Cassegrain, but actually any equatorial telescope will do. Affixing the camera to the telescope is usually quite easy. Many telescope manufacturers make a bracket that bolts to the camera's tripod socket. If you can't find a bracket, it's not difficult to improvise one with aluminum or wood. Try to place the camera close to where the telescope tube balances; your pictures will be sharper because vibration is thereby lessened.

The telescope acts as a platform to keep the camera aimed at one section of sky during the exposure. Because no telescope drive delivers perfect tracking, you need to monitor the tracking and make corrections as needed. A guiding eyepiece ($80) contains an optical grid or cross hairs illuminated by a faint red bulb. With the drive running, place a moderately bright star (3rd or 4th magnitude) on the cross hair and see if it remains in place. Fancy electronic drive correctors are available to let you fine tune the tracking rate and slew back and forth to keep the star centered. For piggyback shots you can ignore the small drifts and correct only the really bad ones, often with nothing more sophisticated than a smooth twist on the slow-motion controls.

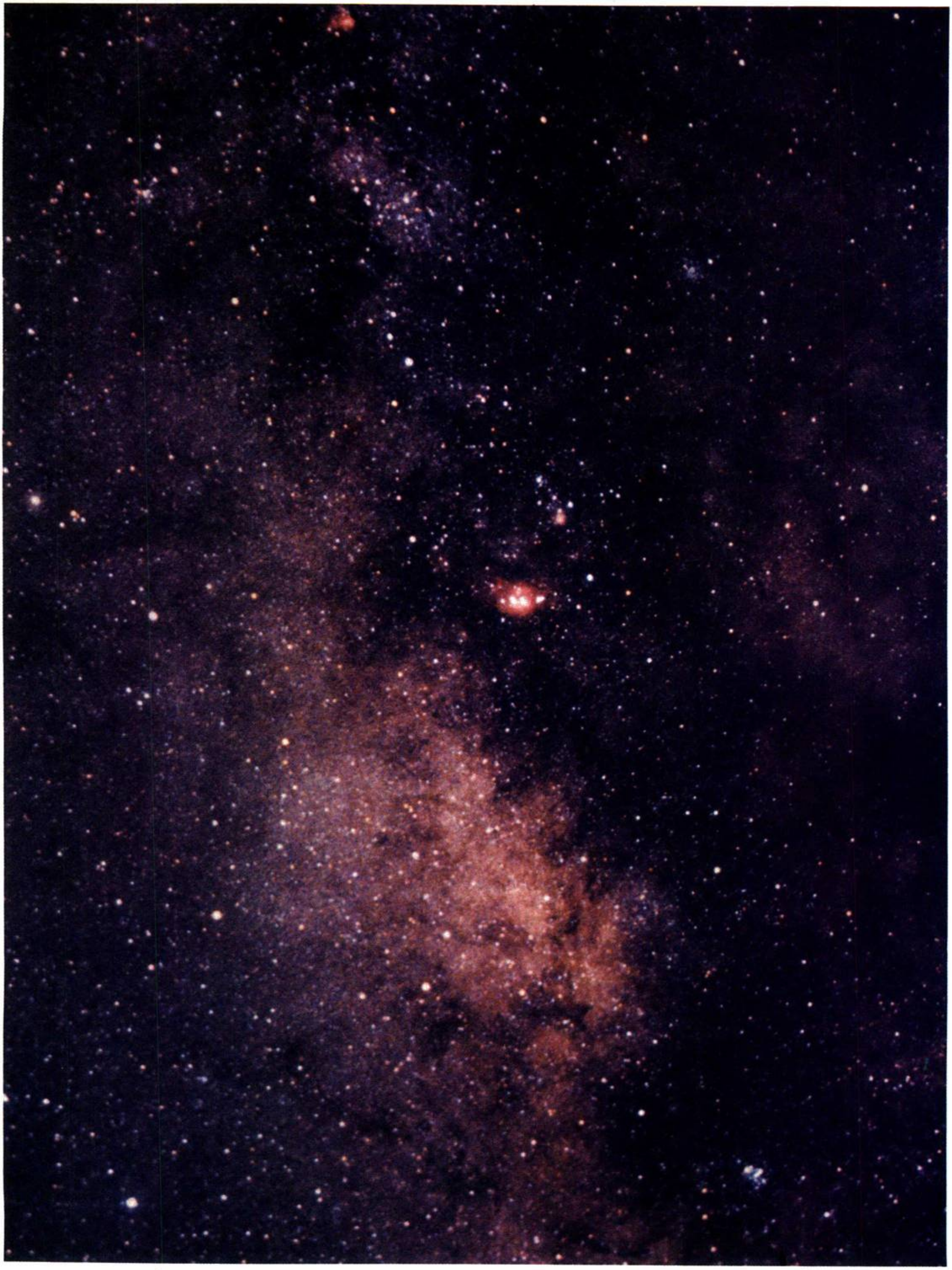
Your camera should be as basic as possible: you control everything and nothing depends on batteries. Forget autofocus, exposure meters, motor winders — all that expensive stuff. You want a camera with the ability to take time exposures (look for a B or T shutter setting), and a lens that lets you focus on infinity and set the aperture yourself. The camera need not be an SLR or even a 35mm, although most astrophotographers like the low cost of 35mm film, the flexibility of interchangeable lenses, and the direct viewing of an SLR. In fact, a used or broken camera body is perfectly adequate if the focus screen is in place, the film advance works smoothly, and the shutter offers a reliable B or T. (You can test these features yourself at a used camera dealer or a swap meet. It might be worthwhile to scout for a cheap junker camera body solely for astrophotography. Just make sure your lenses will fit.)

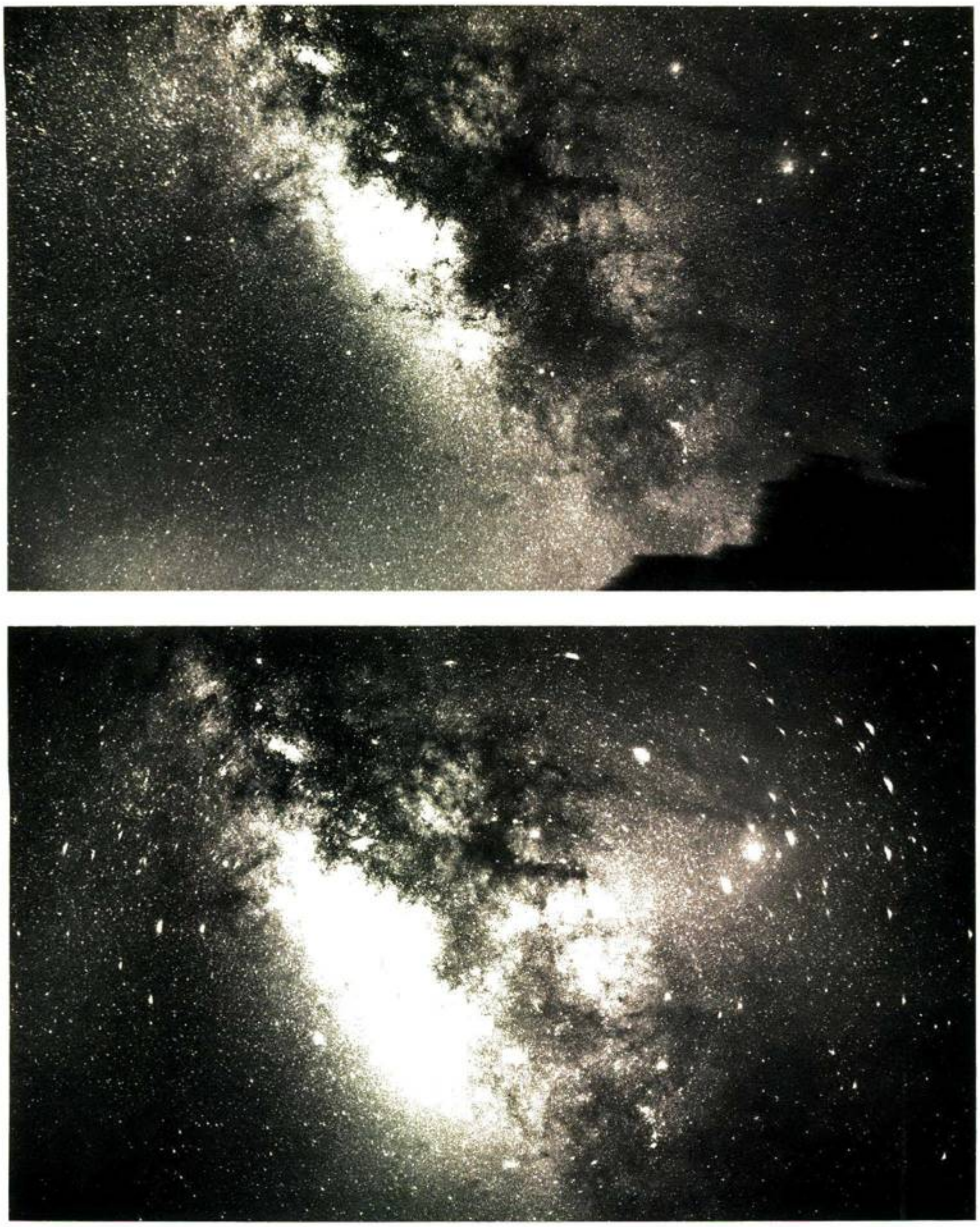
Choosing a lens involves some trade-offs and choices. One important consideration is to make sure a given lens will "see" all the region of sky you want to shoot. For tips on selecting lenses for sky coverage, see the box on page 75.

Piggyback Accessories

A high-quality cable release is important to keep your hand from touching the camera and creating vibration. Buy a release at least 18 inches long and wrapped with steel. (Cloth-wrapped releases can stretch after a time, and the plunger may not extend far enough to trip the shutter.) Expect to pay about $10. The release should have a locking thumbscrew; I find the wedge-type lock is more apt

A SWEEPING VIEW of Sagittarius was captured by Chris Floyd's 35mm lens. The exposure was 55 minutes at f/3.6 on 200 ASA slide film.





CLOSE DOWN THE LENS! The top picture of Sagittarius was taken at f/2.8 for 20 minutes, the lower at f/1.4 for 5 minutes (35mm lens, hypered Tech Pan film).

to let go and waste a shot by ending the exposure prematurely.

I like using a swivel ball-head attachment because it lets me tilt the camera or point it away from the telescope's line of view if I need to. This handy device is available at most photo stores (prices start at about $20) and is especially helpful in keeping the front end of the telescope out of the picture when you shoot with a wide-angle lens. It also allows you to frame a scene vertically, horizontally, or anything in between.

Think about making a dual-camera mounting bracket from scrap wood or aluminum. Running two cameras at once makes skyshooting more productive because you can use different focal lengths, try out color and black-and-white film simultaneously, or even shoot two different objects at the same time.

Lens hoods ($5 each) will slow the formation of dew on your optics, and a hair dryer will remove dew (at least temporarily) and keep you shooting longer into even the most humid nights.

As for film, go for fast color, either print or slide. Try Konica SRV 3200, Fuji HR 1600, or Kodak VR 1000 for prints and Kodak's Ektachrome P800/1600 for slides. Skip the hypersensitized films at first — they demand special handling — but when you've got a few rolls under your belt, give them a try. I'll say more about processing at the end.

A programmable digital countdown timer that beeps when it reaches zero makes timing exposures a snap. Many models are available; I use a Radio Shack Micronta model 63-880. This $15 device can be set up to 99 minutes and 99 seconds, and its magnetic mount keeps it handy at the scope. Additionally, when the hour grows late and fatigue is taking its toll, the digital timer doubles as an alarm clock so I can nap until the predawn objects rise high enough to be photographed.

Tape a checklist of essential items to the inside lid of your observing equipment box. You don't want to arrive at a site sixty miles from home minus some critical item! Besides all the equipment above, the checklist should also include things like extension cords, tools, flashlights, guiding eyepieces, film, and so on.

Planning Ahead

When I plan an evening's photography, I list the targets I wish to shoot. I use a planisphere to find the times when the objects will be highest in the sky. I arrange the list in west-to-east order, noting the locations of nearby bright stars to guide on for each region. Working west to east prevents zigzagging across the sky in a haphazard manner and ensures that I catch those about-to-set areas before they are gone.

Plan to arrive at the observing site just at sundown. This gives you about half an hour of good light to set up your equipment and half an hour of deepening twilight for polar-aligning the mounting and checking the telescope's operation. Then you're ready to start shooting as soon as it gets dark.

By the way, it's a good idea to become thoroughly familiar with your equipment, telescopic and photographic. Can you disassemble it in the dark? You may have daylight to set up with, but it will be pitch black when you pack it away and fumbling with little wrenches and screws by starlight is no fun at all.

When you have planned the skyshooting and assembled your equipment, don't overlook the creature comforts. When you travel miles into the country to spend an evening under the stars, you are basically camping out. Be prepared with warm clothing, a thermos of hot chocolate or coffee, and a decent "night lunch" to revive you when the 3 a.m. droop hits.

Filtering for Better Sky Photos

One last accessory deserves special mention. If you've never used a filter on an astrophoto, a world of wonders awaits you. (With one exception, however: meteors. Never attempt a fil-

NORMAL LENSES can frame large objects. Hal Jandorf photographed Comet West with a 50mm lens at f/1.7 (6 minutes, ASA 500 film).

tered meteor photo because the light loss is too great.) Most 35mm camera lenses can be fitted with ordinary photographic filters and many can be adapted to accept specialized astronomical filters.

Foremost among astronomical filters are those that specifically eliminate light pollution. Even under good, dark skies, experienced astrophotographers use filters to enhance the contrast between the object and the sky background. The most popular filters for piggyback astrophotography are marketed by Lumicon; these include the Deep Sky (approximately $100) and the Minus Violet ($20-$30) filters for both black-and-white and color shooting and the Hydrogen-Alpha filter ($40) for red-sensitive, black-and-white films like Technical Pan.

There is a trick with the Hydrogen-Alpha filter that's becoming popular with those who shoot color film. Using the filter for the entire exposure gives an unacceptably red photo. However, using the filter for just the first half of the exposure lays down a nice red color for the hydrogen-emission objects. Then removing the filter for the second half lets the stars regain a more true-to-life color. (This technique also helps compensate for the weak sensitivity of most color films to the far red.)

A polarizing filter ($10) is useful if you have to photograph a region with the Moon in the sky (a conjunction, for example). Polarizing filters darken the sky background 90° away from the Moon just as they darken the daytime sky 90° away from the Sun. While the amount of moonlight protection isn't great, at times you need all the help you can get to save an important shot.

Stop Down That Lens!

The sky has finally darkened and the time has come to start the first exposure. You center the guide star, engage the drive, and check the camera settings. At this point many astrophotographers overlook a key step in getting quality piggyback photos: closing down the camera lens one or two f/stops from wide open.

Modern 35mm camera lenses are very fast photographically, typically around f/1.4 or f/2. This is great for available light photography under dim conditions — nighttime street scenes — so many people assume it's ideal for astrophotos, too.

Photographing stars, however, is the most severe test any camera lens can be put to. Those pinpoint lights are pitiless in the way they reveal distortions in a fast lens used wide open. While it may seem crazy to stop down a lens when you are trying to collect as much starlight as possible, the improvement in image quality is dramatic. For an example, take a look at the two pictures on page 72.

But doesn't stopping down the lens steal too much light? In my experience, the light loss is usually acceptable. After all, f/2.8 or even f/4 is still a pretty fast focal ratio for astrophotography. With 1600 and 3200 speed films and hypersensitized emulsions, you recover a two f/stop loss fairly easily. Besides, I think exposing for 20 minutes instead of 5 or 10 minutes is an acceptable price to pay for the extra quality of the finished shot.

One final note: If your lens is f/4 or slower at its widest opening or if you are shooting fast, transient objects such as meteors, you need all the light you can get. So use the lens at its widest open setting no matter what the stars come out looking like. (In any case, you're not risking too much because f/4 and slower lenses generally produce very clean images.)

The Finishing Touch

After conquering the elements and mastering your equipment to make excellent sky photos, don't blow the whole thing at the finish line with poor processing. You don't have to do your own darkroom work, nor do you have to pay through the nose to have it done at a custom photo lab. Despite what many people think, it is perfectly feasible to get good results from a one-hour photo lab — provided you approach them the right way and know how to frame your requests. (See "Great Astrophotos in Less Than an Hour" in last month's issue.) Try it and see.

The secrets of great piggyback astrophotos are really pretty simple. A few accessories, a little planning, and a clear night: that's all it takes. The dividends will be some of the prettiest and most rewarding astrophotos you've ever seen. ☐

Robert Reeves is a Texas amateur astronomer and astrophotographer. His most recent article was "ASTRONOMY Tests the Northern Lites Cold Camera" in the July 1989 issue.

A TELEPHOTO LENS requires careful tracking. Jim Barclay used a 200mm lens at f/3.5 and a 1-hour exposure on ASA 1000 slide film for the Eta Carinae Nebula.

Choosing the Right Sized Lens

What lens do you need to capture all of Orion in a single 35mm frame? How many shots with a 28mm lens does it take to map the Milky Way from Sagittarius to Perseus? To answer questions like these, you need to know how much sky a lens with a given focal length will capture in a camera frame of a given size.

The basic formula for calculating the field of view is:

$$\mathbf{A = 2\ arctan\ (S/2F).}$$

A is the angle in degrees, S is the side of the frame measured in millimeters, and F is the lens focal length, also in millimeters. (Thirty-five millimeter frames measure 24mm x 36mm, so a 50mm lens takes in a field measuring 27° by 40°.)

Using the formula and a calculator with trig functions, prepare a table that gives the angular fields of view for whatever lenses you have. Zoom lenses, by the way, pose special problems. Astrophotographers tend to shun zooms because they are one or two stops slower in maximum aperture than comparable fixed lenses, and their extra lens elements promote more internal reflections and rob a bit more light. But if a zoom is all you have, pick representative focal lengths from the range and compute their fields of view.

Now turn to your favorite star atlas and measure how big the field of view is for each lens. (The frame size won't be precisely the same from map to map or from place to place on a single map because of the distortions inherent in all map projections.) Make a cardboard overlay for each lens with a cut-out window the size of the frame, or mark a transparent sheet of acetate with an India ink or technical pen. Place the overlay onto your star atlas and plan your exposures by seeing directly how much sky each lens will photograph. — *Barry Simon*

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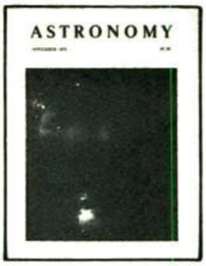

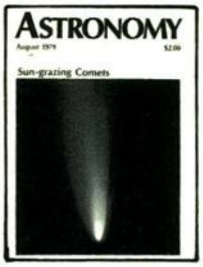

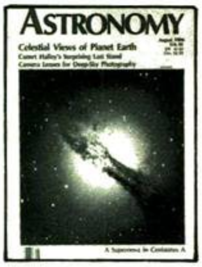
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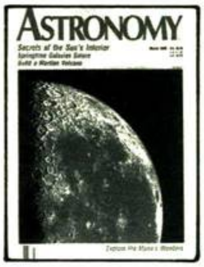

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Autumn's Galaxies: The Best and the Brightest

This is the perfect time of year to explore the sky's brightest galaxies.

by Max Radloff

Galaxies stir almost everyone's imagination. These vast, stately mansions range from dwarfs to giants and contain from a few million to hundreds of billions of stars. In shape, they can be elliptical, spiral, barred, or irregular, and we see them at any angle between edge-on and face-on. Each is a universe of stars by itself; and with a 6-inch or 8-inch scope you can explore not only their variety of shape, but also some of their internal components, such as star clouds, nebulae, dust lanes, and even globular clusters.

Fortunately, the autumn sky displays the best and brightest galaxies, conveniently placed for evening viewing. As if to make viewing galaxies ideal, cool autumn nights are typically free from summer's haze, presenting the year's best, most transparent evenings.

Autumn's greatest showpiece is the **Andromeda Galaxy**, M31 (NGC 224), the largest and brightest spiral galaxy in the sky. With a mass 300 billion times that of the Sun, the Andromeda Galaxy is one of the most massive galaxies in our local part of the universe. Its distance of 2.2 million light-years makes M31 the most remote object visible to the unaided eye.

On early star charts M31 appears as *nebulosa*, Latin for "misty or foggy." This description fits its naked-eye appearance well. In moderately dark skies the galaxy is visible as an elongated, hazy patch, slightly brighter in the center, and fading away on the edges until it blends into the sky background so gradually that you can't quite say when it disappears. Under average conditions the galaxy appears about 1° long, but its apparent length doubles when viewed under a truly dark sky. M31's appearance is quite sensitive to sky conditions. After you're familiar with it, a glance at the galaxy serves as a good indication of how dark and transparent the sky is.

In binoculars and small telescopes M31 is an impressive sight. The light from the galaxy's millions of stars combines into a smooth, milky glow that more than fills a low-power field. The galaxy's light brightens dramatically to a stellar nucleus. This rise in brightness from edge to center is even more striking at high powers.

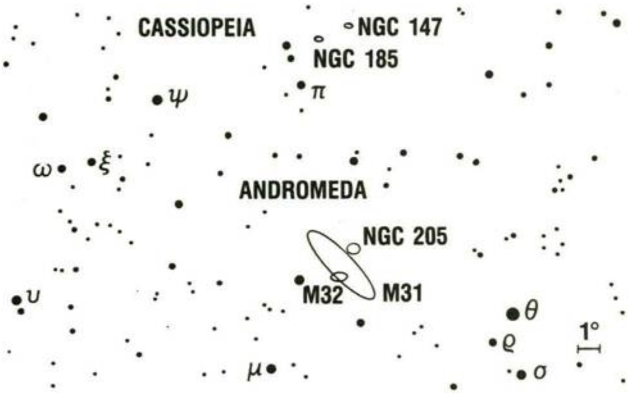
Close observation of the entire galaxy reveals that M31's light does not glow uniformly. On the galaxy's northwest side, the light fades smoothly toward the edge, but it suddenly cuts off, reappears, cuts off again, and again reappears more faintly before finally fading completely. The light disappears behind two thin lanes of dust that encircle the galaxy, obscuring the light from stars lying behind them. If M31 is not too high in the

M32
Magnitude 8.2 Size 8′ by 6′
by Mike Sisk

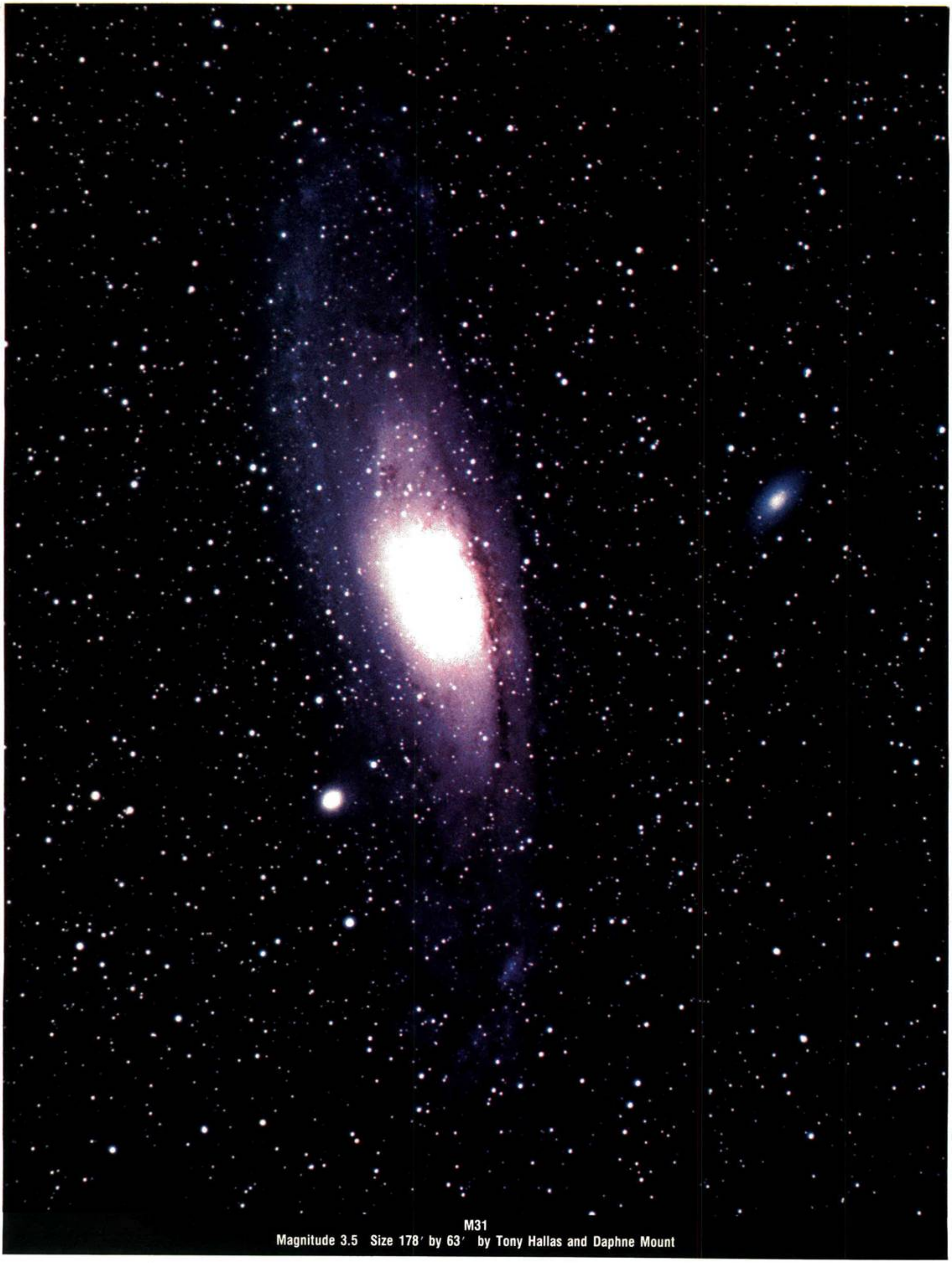
NGC 205
Magnitude 8.0 Size 17′ by 10′
by Martin C. Germano

NGC 147
Magnitude 9.3 Size 13′ by 8′
by Roger Sliva

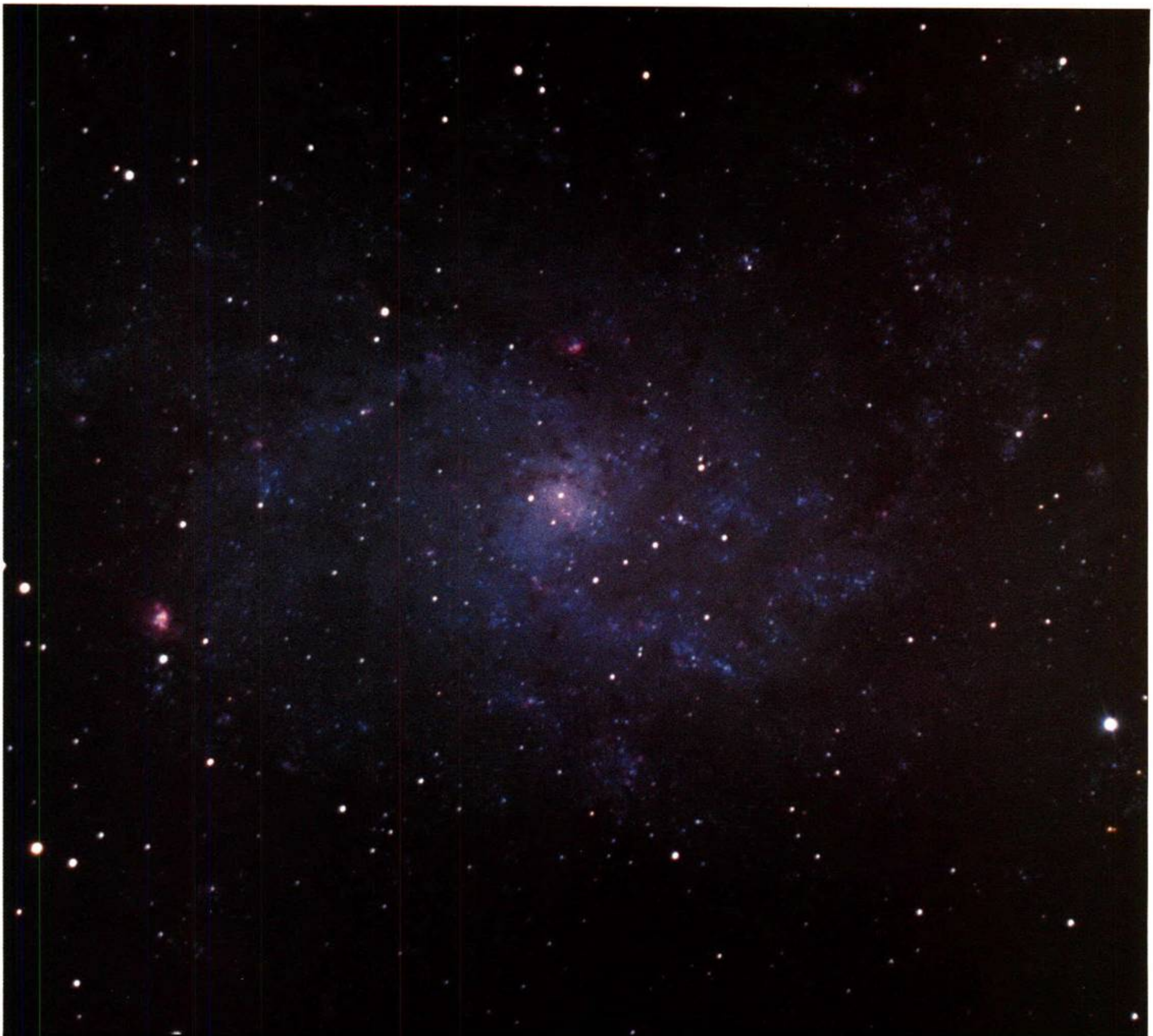
NGC 185
Magnitude 9.2 Size 11′ by 10′
by Martin C. Germano



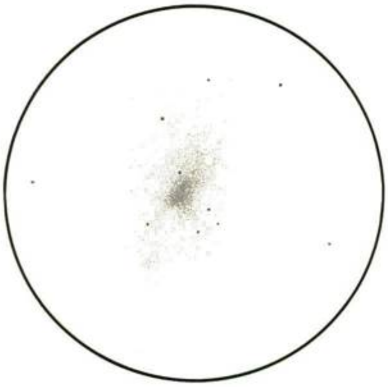
THE BRIGHTEST SPIRAL GALAXY in the sky, M31 in Andromeda is visible to the naked eye as an oval patch of light. Telescopes reveal dust lanes and ghostly spiral arms.



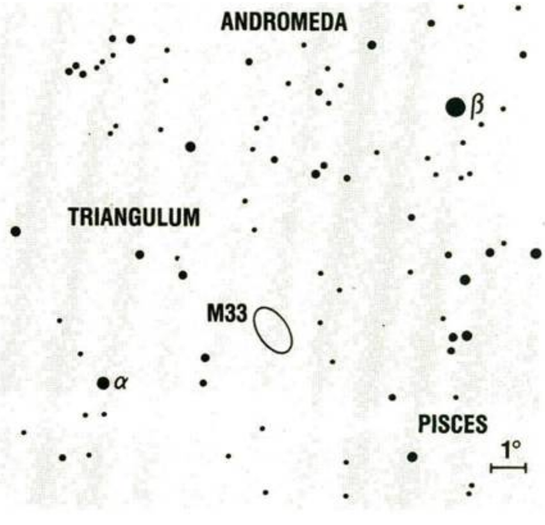
M31
Magnitude 3.5 Size 178′ by 63′ by Tony Hallas and Daphne Mount



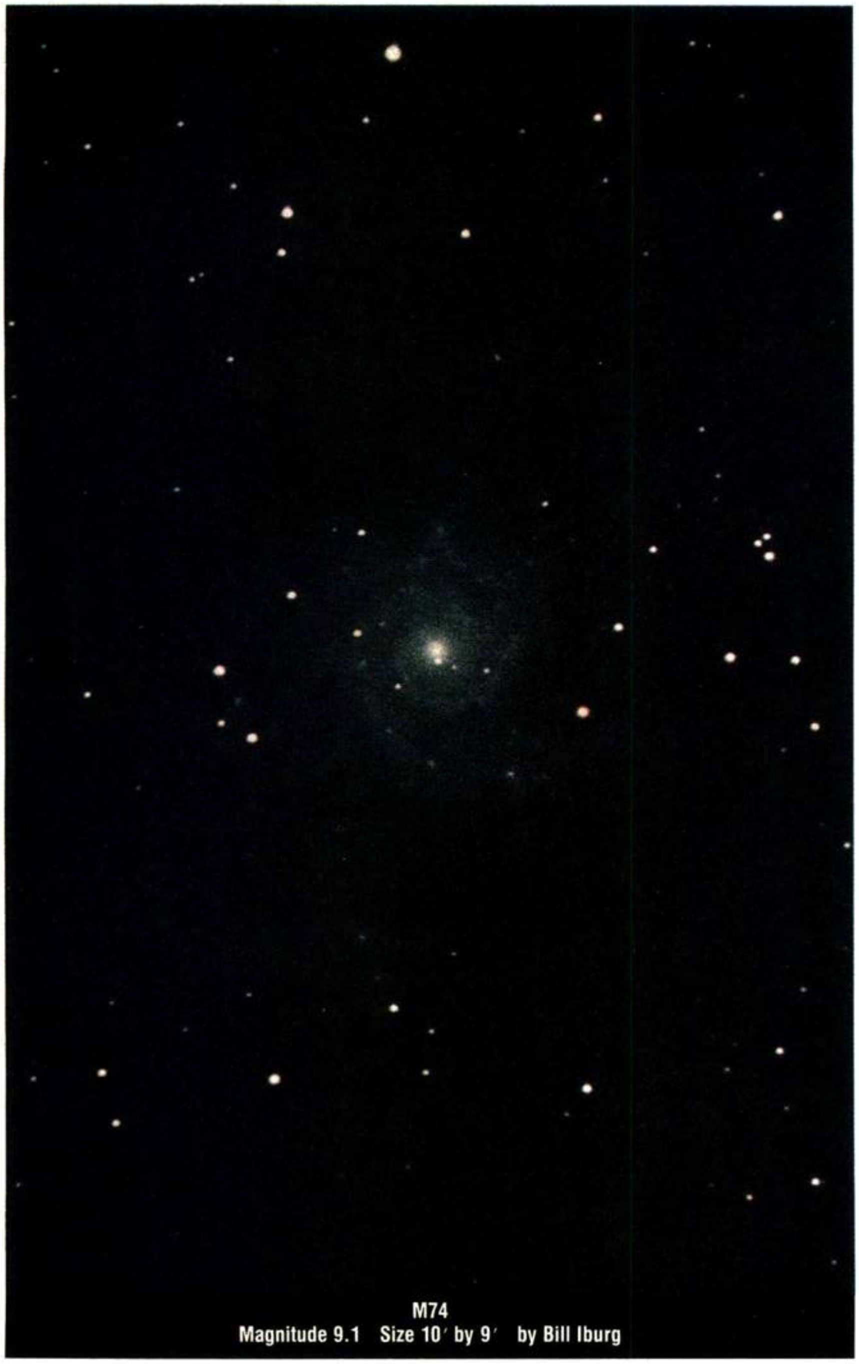
M33
Magnitude 5.7 Size 62′ by 39′ by Tony Hallas and Daphne Mount

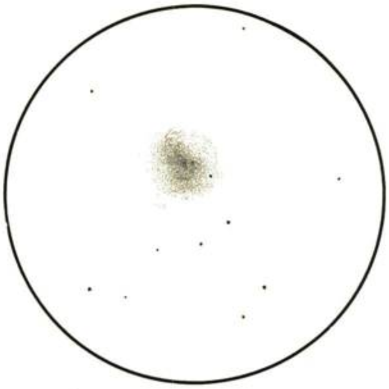


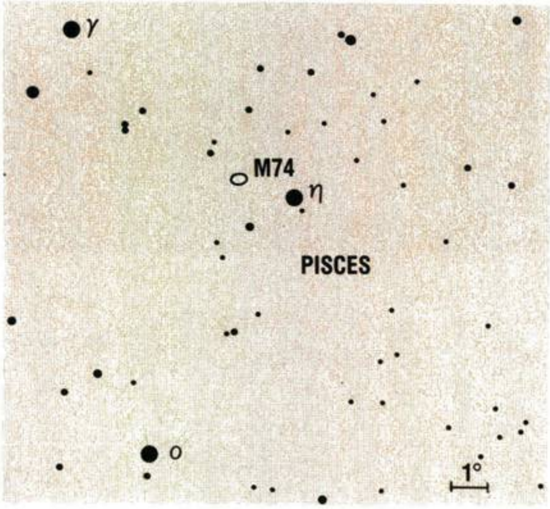
M33
17.5-inch f/4.5 Reflector at 71x
by David J. Eicher


ANDROMEDA
β
TRIANGULUM
M33
α
PISCES
1°

SPIRAL STRUCTURE is easily visible in galaxy M33 on a dark night. This galaxy contains one of the largest known nebulae.


M74
Magnitude 9.1 Size 10′ by 9′ by Bill Iburg


M74
8-inch f/10 SCT at 50x
by David J. Eicher



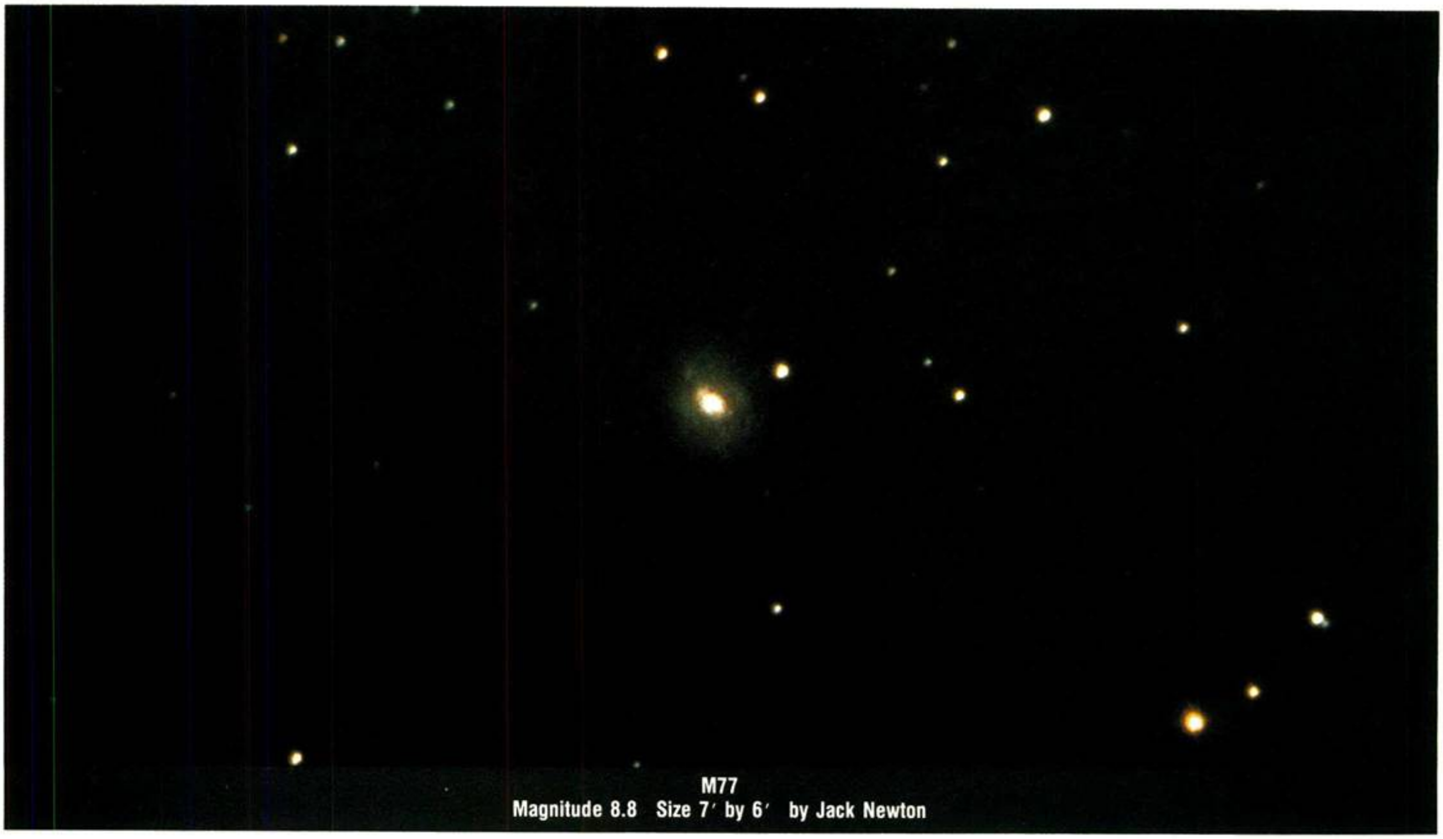
THE FACE-ON SPIRAL M74 is a challenge to find on less-than-dark nights. The galaxy's arms require averted vision and a clear, moonless sky.

eastern sky, take a look west and you can see this same phenomenon in our own Galaxy. Called the "Great Rift," it divides the Milky Way from Cygnus to Ophiuchus into two streams of light. Under excellent conditions, the dust lanes in M31 can be traced along much of the length of the galaxy and seem to have irregular edges. Under really black skies, the dust lanes give M31 a three-dimensional appearance.

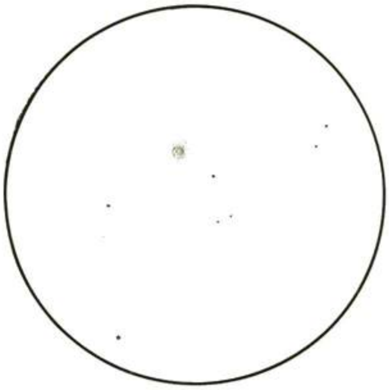
About 1.5° southwest of the nucleus along the major axis of the galaxy lies an enormous star cloud. This object was prominent enough to nineteenth-century observers to receive its own NGC number, **NGC 206**. This object measures 4′ by 2′ and appears as a patch of light brighter than the rest of the galaxy that surrounds it. In physical terms this star cloud is a dense grouping of intrinsically bright stars that spans some 3,000 light-years. NGC 206 is visible in a 3-inch telescope under a dark sky. Observers with larger scopes may see much fainter patches of light along the galaxy, which mark the positions of dimmer star clouds.

With an 8-inch or larger telescope, look for a few of the brightest globular star clusters surrounding the Andromeda Galaxy. Because they glow at 13th magnitude, these globulars are challenging objects that require a detailed finder chart showing their exact locations. They also require enough patience to star hop through dense starfields to identify the clusters. If you want to take on the challenge, see the finder chart in the Autumn 1984 issue of *Deep Sky* magazine.

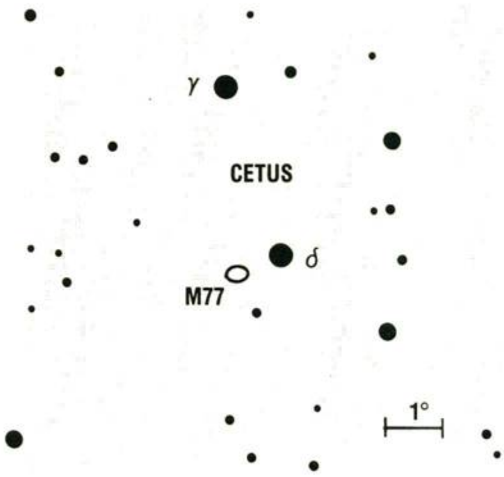
Beginning observers are sometimes disappointed when viewing galaxies, seeing only some feeble light with little apparent detail. One essential element for galaxy observing is a reasonably dark sky. If you live in a light-polluted area, you'll have to drive to a dark-sky site. Beyond that, galaxy observing requires only a little common sense, a few tricks, a measure of patience, and



M77
Magnitude 8.8 Size 7′ by 6′ by Jack Newton



M77
8-inch f/10 SCT at 170x by David J. Eicher

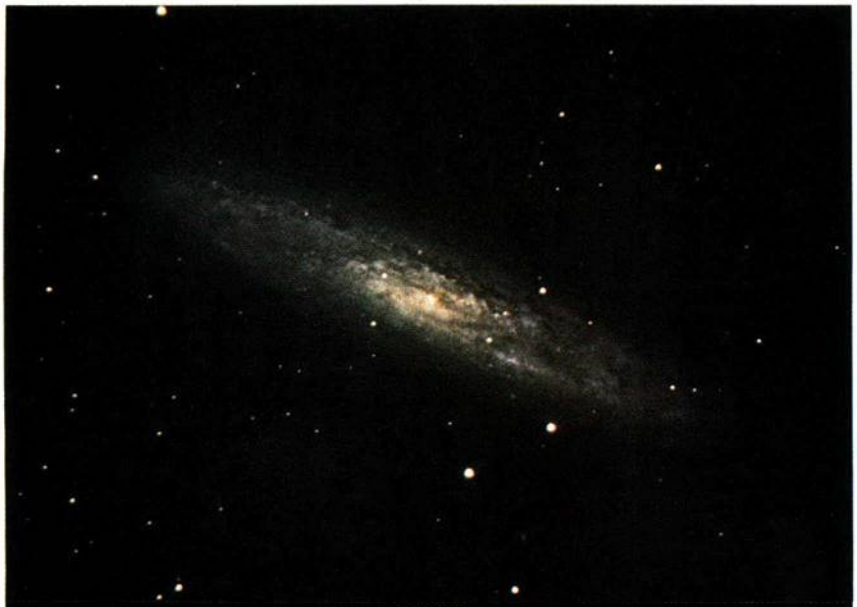


TINY M77 in Cetus is a tightly wound spiral with an intensely bright nucleus. Locate M77 by aiming 1° southeast of Delta Ceti.

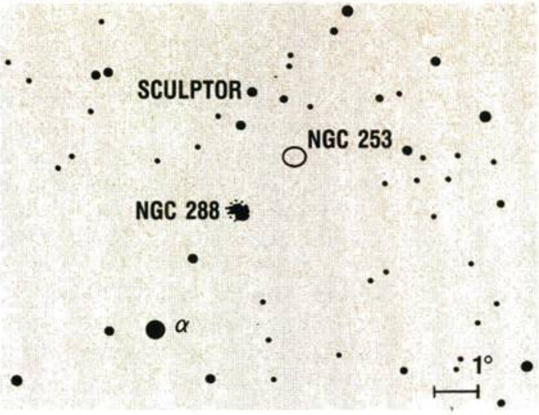
experience.

A number of little factors will improve your galaxy viewing. Start with a well-collimated telescope with clean optics and eyepieces. Try to observe on the darkest, most transparent nights when the dew point and humidity are low. Drive a little farther than usual to reach the darkest site you can. Make sure that once you get there, you dark-adapt your eyes to maximum sensitivity. Although half an hour is usually considered sufficient, being in the dark for two or three hours will heighten your eye's sensitivity to faint light even more. Use averted vision — glancing to one side of the field — to see the most detail you can. Gently move or rock the telescope because your eye is especially sensitive to motion. This will help with spotting particularly faint details. And finally, don't be afraid to use high powers on faint objects like galaxies. The eye can see details in large, faint objects better than in small, bright ones.

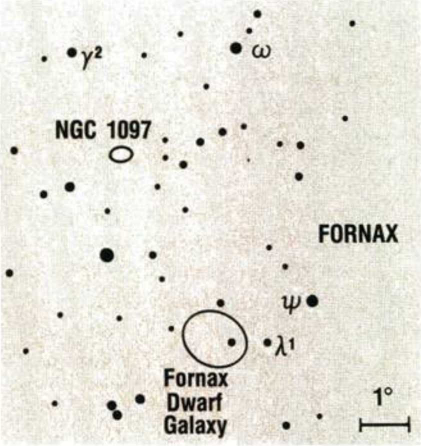
The Andromeda Galaxy has eight known satellite galaxies. Four of these are visible in small telescopes, two of them within the same low-power field as M31 itself. (Four of the galaxies are beyond the reach of amateur instruments.) **M32** (NGC 221) is a small elliptical galaxy only about one hundredth the size of M31. It is visible in binoculars about 25′ south of the nucleus of M31 as one of a pair of 8th-magnitude "stars." The point of light to the southwest is a star in our Galaxy and the one to the northeast is M32, thousands of times more distant and distinguishable by its fuzzy, nonstellar appearance. Through a telescope, M32 shows a bright nucleus with its light gradually fading toward the edges. Elliptical galaxies normally show no details through the eyepiece other than these gradations of light, although images from the largest telescopes show that M32 has dust lanes and a few small star-forming regions. M32's bright nucleus and high surface brightness make it well



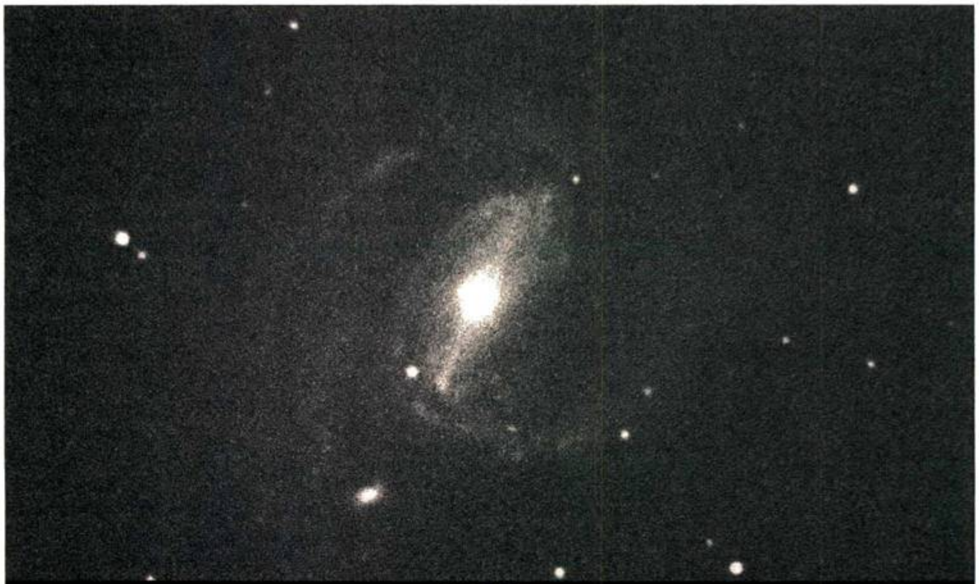
NGC 253
Magnitude 7.1 Size 25′ by 7′ by Bill Iburg



WONDER OF THE SOUTH, galaxy NGC 253 in Sculptor rides low on the horizon for Northern Hemisphere viewers. Nonetheless, the galaxy's huge size and brightness make it one of the sky's greatest attractions.



BARRED SPIRAL NGC 1097 in Fornax is visible in small telescopes as a circular patch of light surrounded by a mottled haze. On exceptionally dark nights the galaxy's bar is plainly visible at high power.



NGC 1097
Magnitude 9.3 Size 9′ by 7′ by Martin C. Germano

worth examining at moderate and high powers.

The other companion galaxy near M31 is **NGC 205**, sometimes identified as "M110." This object is technically not included in the Messier catalog. Although Messier knew of this object in his lifetime, he learned about it after the final publication of his list. NGC 205 is located 40′ northwest of the nucleus of M31. Like M32, it is a small elliptical galaxy, but NGC 205 is larger and far more elongated than M32. It is enlightening to compare the two galaxies under different sky conditions. Both produce nearly the same amount of light; but because NGC 205 is larger and its light more spread out, it appears dimmer than M32.

Two more satellite galaxies of M31 lie 7° away in the neighboring constellation Cassiopeia. Both are also small ellipticals, comparable in size to the star cloud NGC 206. The visual appearance of **NGC 185** is similar to that of NGC 205, only slightly smaller and fainter. NGC 185 is not quite as elongated as NGC 205, but like NGC 205 it has a faint stellar nucleus. In a dark sky NGC 185 is visible with a small telescope, but even a moderate amount of sky brightness can make spotting it quite difficult.

Even fainter is **NGC 147**, another satellite galaxy lying just east of NGC 185. A 6-inch or larger telescope shows this galaxy; but because of its very low surface brightness, sky conditions are important. Look for NGC 147 on the darkest of nights and try all the observing tricks if you don't see it right away. NGC 147 appears as a faint, glowing patch with no detail.

Another member of the Local Group of galaxies provides the best opportunity to explore the spiral arms of a galaxy. **M33** (NGC 598), also called the Pinwheel Galaxy, is a nearby spiral that is much smaller than the Milky Way. Luckily for galaxy observers, this loose spiral is tilted about halfway between face-on and edge-on to our line of sight, allowing a good view of its arms. M33 is at the edge of naked-eye visibility, visible only as a tiny patch of fuzz on the darkest nights. In binoculars or a 2-inch telescope, however, M33 appears as a large, pale, ghostly oval about the size of the gibbous Moon. Because of its low surface brightness, many observers have difficulty locating M33. The key is to search from a dark-sky site using the widest field possible; this shows M33 as an impressive object, filling most of the field of view. From the galaxy's bright central area, two spiral arms extend outward in the shape of a backwards "S," and the entire area around them is filled with a diffuse glow.

About 12′ northeast of M33's nucleus lies **NGC 604**, an enormous complex consisting of stars, gas, and dust. At 11th magnitude, this object is easily visible in small scopes even at a distance of 2.5 million light-years, and it forms a pair with a field star of similar magnitude. NGC 604 is similar to the Orion Nebula but is thirty times larger, measuring 1,000 light-years in diameter. Examining NGC 604 with high power and a nebula filter shows subtle striations and details in its structure.

If you observe M33 patiently, you can see other details. Using medium powers and gently moving the telescope's field will show you a few star clouds and dust lanes, and the two prominent spiral arms contain numerous bright patches. M33 has not produced any recorded supernovae, but its active star-forming regions, loaded with blue supergiants, make M33 the type of galaxy where a supernova is likely to appear.

Similar to M33 in a number of respects is **M74** (NGC 628) in Pisces, a face-on spiral with a low surface brightness. M74 can be difficult to find, and it is rated by many observers as one of the most challenging of the Messier objects. M74 is much smaller than M33 because it is twelve times as distant. Spotting M74's spiral arms is a challenging test of observing skill, but using moderate powers on a dark night will show them as subtle areas in the galaxy's outer glow.

M77 (NGC 1068) is the brightest of a small group of galaxies surrounding the bright star Delta (δ) Ceti. M77 is small but bright, and at a distance of about 60 million light-years it appears in binoculars as a 9th-magnitude "fuzzy star." Telescopically, M77 appears as an irregularly shaped patch of haze with a very bright nucleus. M77 is the closest of an exotic class of galaxies called Seyferts, named after the astronomer who discovered them, Carl Seyfert. Seyfert galaxies have anomalously bright and energetic nuclei and behave somewhat similar to quasars, although they are not nearly as powerful. Once you've located M77, switch to high power to examine the galaxy's intense nucleus and the bright areas around it. With a 12-inch or larger scope you may detect some of the galaxy's tightly wound spiral arms.

NGC 253 is a member of the Sculptor Group of galaxies, the closest group beyond our own Local Group. Distances to galaxies are still hotly debated, but a distance of about 6 million light-years is probably accurate for the Sculptor galaxies. NGC 253 is the brightest galaxy visible from northern latitudes not listed in the Messier catalog, and it is brighter than all but a handful of those observed by Messier. In binoculars NGC 253 appears as a prominent, tapering, dish-shaped glow over 20′ long. Telescopes show NGC 253 as an impressive sight, revealing a bright, elongated oval nebulosity similar in appearance to but smaller than the Andromeda Galaxy. Because of the southern declination of NGC 253, northern observers have difficulty seeing detail in this galaxy; the only routinely visible details are a bright, ball-like nucleus, a bright central hub, and mottled light and dark areas along the galaxy's arms. On the other hand, Southern Hemisphere observers can see dust lanes, bright patches in the galaxy's arms, and patchy knots of dust.

Great Autumn Galaxies

Object	R.A. (2000.0)	Dec.	Mag.	Size	*Tirion*	*Uran.*
NGC 147	0h33.2m	+48°30′	9.3	13′ by 8′	4	I: 60
NGC 185	0h39.0m	+48°20′	9.2	11′ by 10′	4	I: 60
NGC 205	0h40.0m	+41°41′	8.0	17′ by 10′	4	I: 60
M32	0h42.7m	+40°52′	8.2	8′ by 6′	4	I: 60
M31	0h42.7m	+41°16′	3.5	178′ by 63′	4	I: 60
NGC 253	0h47.6m	−25°17′	7.1	25′ by 7′	18	II: 306, 307
M33	1h33.9m	+30°39′	5.7	62′ by 39′	4	I: 91
M74	1h36.7m	+15°47′	9.1	10′ by 9′	10	I: 173
M77	2h42.7m	−00°01′	8.8	7′ by 6′	10	I, II: 220
NGC 1097	2h46.3m	−30°17′	9.3	9′ by 7′	18	II: 354

Object: Designation in Messier or NGC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude of galaxy. **Size:** Diameter. ***Tirion:*** Chart on which object appears in *Sky Atlas 2000.0* by Wil Tirion. ***Uran.:*** Chart on which object appears in *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi.

The bright galaxy **NGC 1097** in Fornax is the only barred spiral in our survey. At a declination of −30°, northern observers may be tempted to pass by this object. However, NGC 1097 is clearly visible because of its size and brightness. In telescopes NGC 1097 has a bright, round nuclear glow surrounded by a diffuse, oblong halo of greenish light. Catch this galaxy when it's near the meridian in a 6-inch or 8-inch scope and you'll be able to spot its distinctive bar, which runs along the length of the galaxy. Just beyond the bar on the galaxy's northwest end lies a 13th-magnitude companion galaxy.

Difficult as it may be to comprehend the enormous sizes of galaxies, they are in turn parts of even larger structures in the universe. An enormous string of galaxy groups and clusters begins with the Sculptor Group on the southern horizon near the south galactic pole and contines through the Local Group to the Milky Way. This string of galaxies continues on the other side of the Local Group and stretches into groups of galaxies in Ursa Major and Canes Venatici. Still more groups follow along the northern horizon past the north galactic pole to the heart of the Virgo Cluster and beyond. Altogether, this association of galaxies spans at least 100 million light-years. Although it taxes the imagination to visualize a string of thousands of galaxies, each with many millions of stars, this is only a fragment of the observable universe. When you're under the stars enjoying the views of autumn's great galaxies, take a few moments to think about the immensity of it all. You'll feel just a little differently about the world after you go back inside. ☐

Max Radloff is secretary of the Minnesota Astronomical Society and is directing the planning of their new observatory. He also writes articles for Deep Sky *magazine.*

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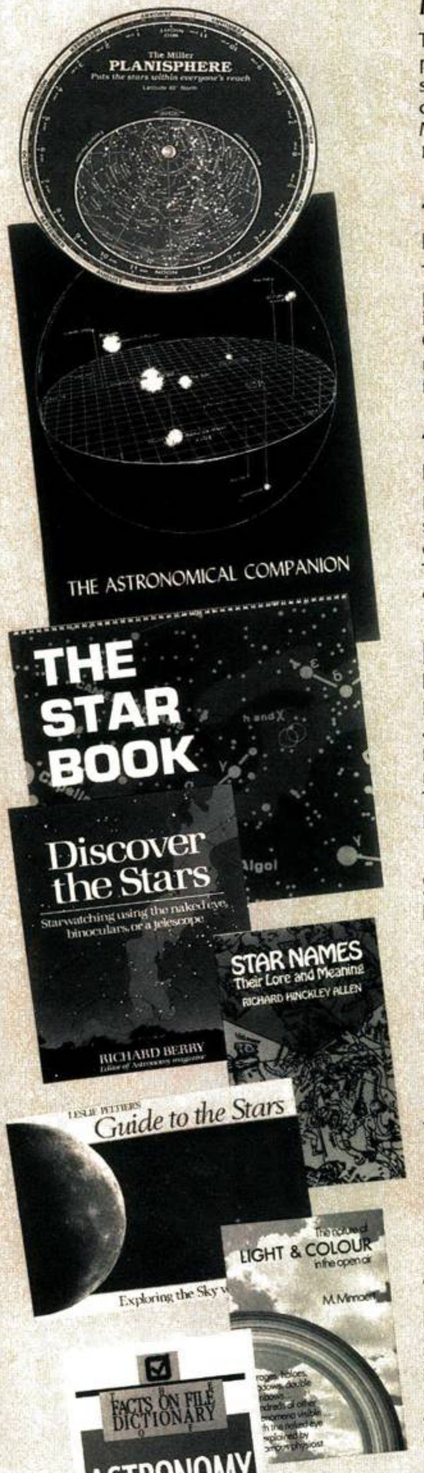

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Recording the Sky on Videotape

Astronomy video pioneer David Brewer talks about how he creates stunning videos of the Moon and planets.

by M. Barlow Pepin

Video astronomy has arrived. All you need to collect and view your own real-time video images of the universe is an equatorially mounted telescope, an off-the-shelf videocamera, a television, and a videocassette recorder/player (VCR). Tapes, cables, and accessory "black boxes" round out the necessary equipment. Nearly every home in America contains at least one television, and over half have a VCR. Many ASTRONOMY readers own or have access to an equatorially mounted telescope. The videocamera is fast becoming a popular item for making family movies. However, a videocamera can also double as a powerful tool for backyard astronomy.

The technology for do-it-yourself astronomy videos is easily available, but for many would-be video astronomers the process is new and unfamiliar. The techniques for video astronomy require specialized knowledge and plenty of practice. Floridian David Brewer is a video astronomer with six years of experience under his belt. A graphic arts photographer by profession, Brewer has produced high-quality videos of the Moon and planets. In a recent conversation, Brewer predicted a bright future for the new and exciting marriage between astronomy and television.

ASTRONOMY: What do you find exciting about video astronomy?

BREWER: It excites me because it provides the opportunity to capture real-time astronomy events on tape and enjoy them indoors on cloudy nights. A few weeks ago I recorded the transit of a Jovian moon's shadow across Jupiter. Later, after the on-the-spot excitement of the event, I enjoyed watching the images again, reliving the experience in my mind. It's like having a great observing notebook filled with colorful images.

Video astronomy also allows me to share events with other people. At last year's Mars Watch at the Orlando Science Center we rigged up a giant video screen and showed nearly six thousand people "live" images of the Red Planet. It's a powerful way to promote interest in astronomy and conduct astronomy education on a mass scale.

ASTRONOMY: Can video astronomy be used for advanced observing projects?

BREWER: The fact that you can record events as they happen and analyze them later lets you record occultations, meridian crossings of Jupiter's Red Spot, transits of various solar system moons, lunar and solar eclipses, and changes in phenomena like sunspots and shadows over lunar craters for posterity. Capturing these events on tape allows me simply to relax and play technician at the telescope and interpret the results at my leisure.

ASTRONOMY: Astrophotography lets you do the same thing. Does video astronomy offer any unique advantages?

BREWER: It's a little like comparing motion pictures with still photographs. Because television is a dynamic medium, it contains more information than still photos. Video astronomy captures entire events as they happen in real time, not individual moments of events. It's similar to having a group of thousands of consecutive astrophotos, and you can refer back to any one you want. You can view individual frames in a tape in order to capture moments of extremely good seeing.

The advantage of getting around seeing is significant. When you're capturing thirty frames per second, you invariably get frames that show moments of good seeing somewhere on the tape; you can pick these frames out and freeze them on the screen when you watch the tapes. The fact that you're shooting so many frames per second also helps smooth out atmospheric turbulence as it happens.

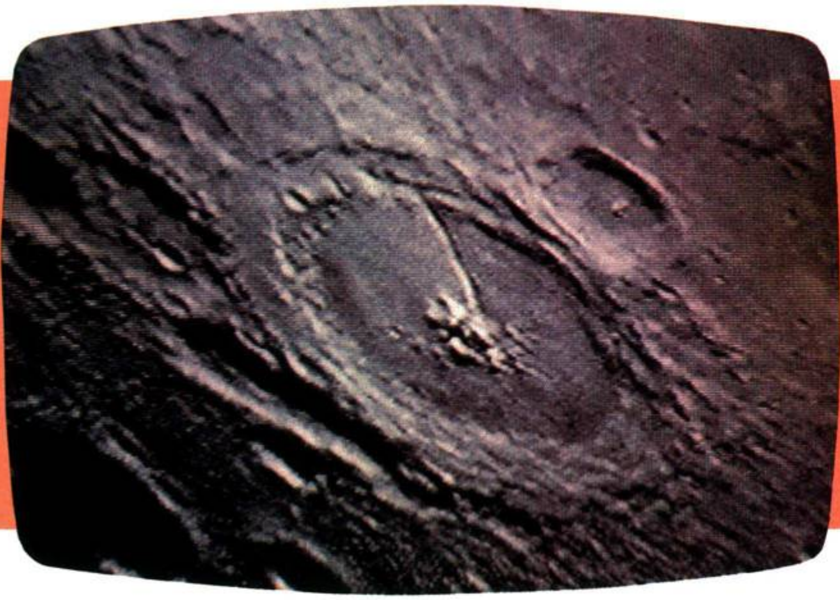
Video astronomy is more comfortable than astrophotography. You can work under reasonable lighting conditions, which means you don't need to worry as much about doing everything in total darkness. Also, there's much less eye strain because you're watching a monitor rather than peering into an eyepiece. You can even take it one step further by putting the monitor inside your house and observe, via cables, while you keep an eye on the kids or simply unwind from the workday in indoor comfort.

ASTRONOMY: Suppose I want to get into video astronomy. What equipment do I need?

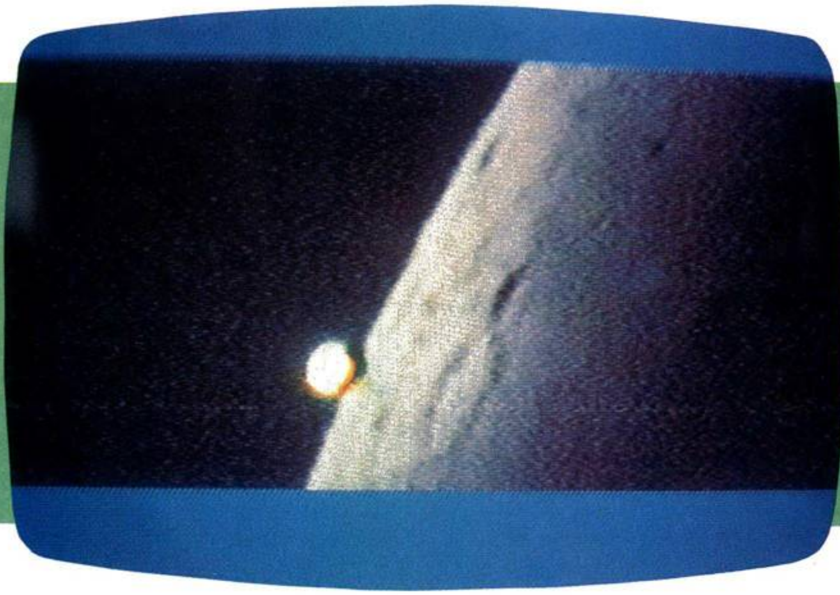
BREWER: Apart from a good telescope that can accurately track stars, you'll need a television set; a videocassette recorder; a good, versatile videocamera; and a bunch of accessories like cables and tapes.

The videocamera is by far the most important consideration. You want a camera with a removable lens so you can easily attach the camera body to the telescope with a standard C-mount. This makes the system easily adaptable for use at your telescope's prime focus.

ASTRONOMY: Why are you using a camera that is

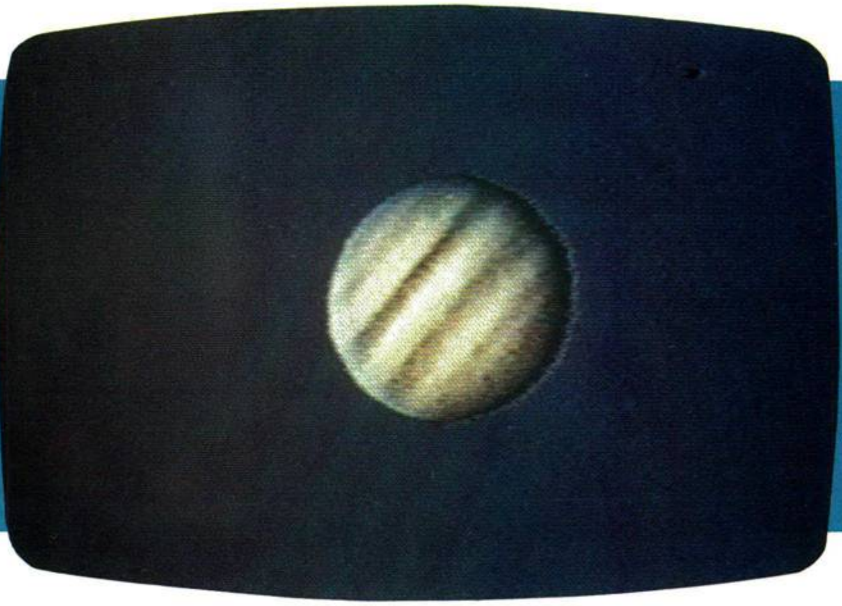


THE LUNAR CRATER PETAVIUS shows central peaks and a long, thin rille in this video image. All photos in this article are still frames from videotapes made by David Brewer with an 11-inch f/10 SCT and a Panasonic D5000 camera. Photos by M. Barlow Pepin.

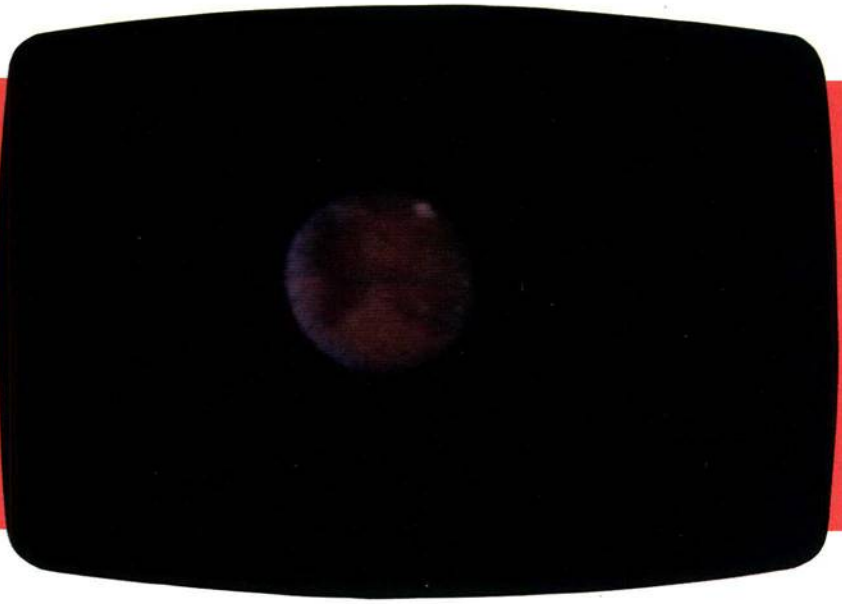


VENUS SLIPS BEHIND THE MOON in an image made in 1987. Video astronomy easily records bright solar system phenomena such as occultations, satellite transits, and planetary surface details.

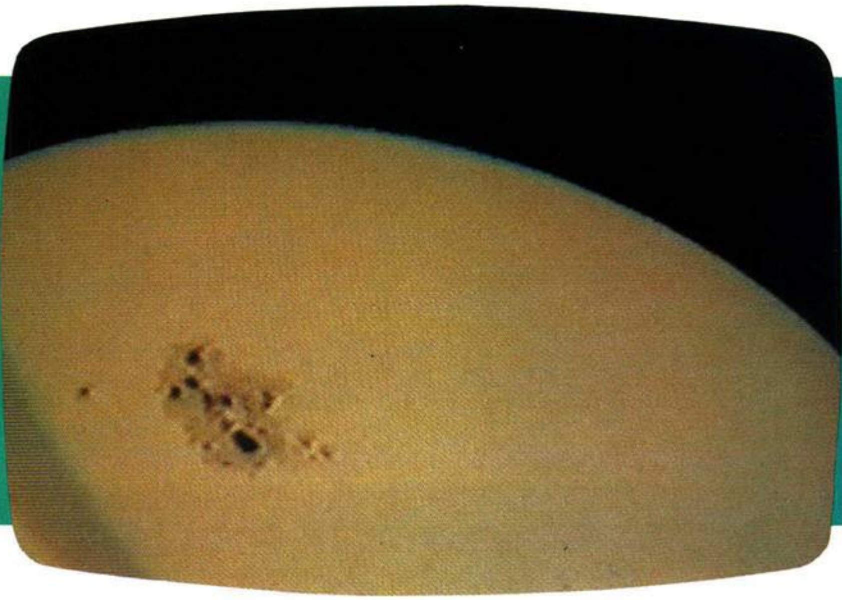
CLOUD BANDS AND BELTS on Jupiter stand out distinctly in this video image. Jupiter's moon Io lies at upper right.



MARTIAN ALBEDO FEATURES are abundant in this video image, made during the 1988 Martian opposition. This shot shows Syrtis Major at left, the south polar cap at top, and a prominent, bluish limb haze.



LARGE SUNSPOTS are easily recorded on video systems using standard solar filters on the telescope. This spot group triggered the major solar flare on March 11, 1989.



separate from the video recorder unit? Is it possible to use a camcorder?

BREWER: In my experience it's best to use a camera that does not have the recorder built in. This keeps the weight of the unit that you attach to the telescope at a minimum, so you get a lot less vibration than you would with a camcorder.

Even if you know you want a separate camera, it's quite tricky to choose the one that's best for you. Some of the cameras I have tried lacked versatility. For instance, some off-the-shelf cameras work well only for imaging the Moon. They're not sensitive enough to image planets or planetary satellites. Others have good sensitivity to light but poor resolution.

ASTRONOMY: What's the best way to make sure you get the right camera?

BREWER: The best approach is to make an arrangement with the seller to try the camera out on your telescope before buying it. If you can't do this at the local camera store, try to find an outlet that caters to professional video users. Most of these businesses have a staff technician whom you could explain your situation to and get advice from. You can get a lot more assistance with the purchase if the sales staff is capable and if you're taken as a serious customer rather than a home-entertainment buff.

ASTRONOMY: What camera are you currently using?

BREWER: A Panasonic D5000. It's an integrated, single-chip CCD camera that weighs 9 pounds and attaches to my scope with a C-adaptor. It has a 0.66-inch pickup tube and provides an image with 574 horizontal pixels by 499 vertical pixels. The D5000 puts out between 400 to 450 lines of resolution across the screen and has a sensitivity of 7 lux. (Lux is a measure of the dimmest light the camera can record. The lower the lux number, the fainter the objects you can record.)

ASTRONOMY: And you couple the camera to a Schmidt-Cassegrain telescope?

BREWER: Yes, that's simply what I had when I began — an 11-inch f/10 SCT. Actually, any telescope that has its prime focus at the back end should work reasonably well. Working at the back end of the telescope gives you a stable instrument platform and makes it relatively easy to counterweight the camera and run the cables off to the monitor and recorder.

ASTRONOMY: Do you need a special mount for the scope?

BREWER: As far as mountings go, the name of the game is sturdiness. Shaky, wobbly tripods won't allow you to track accurately and will deliver nothing but frustration when you view the final tapes. You need a mount that is absolutely solid and a drive corrector and guiding set up that maintains smooth, accurate tracking over long periods. This is essential.

ASTRONOMY: How does the procedure work for the system you currently use?

BREWER: The light from a planet or star strikes the CCD inside the videocamera and gets divided into pixels. After it is converted into an electronic signal, the information is fed into a "black box" device called a color corrector, a common item for professional videographers. This instrument allows you to adjust the color balance of the feed you're getting as it goes on the tape.

The color corrector is incredibly useful for producing satisfying tapes because it lets you change the saturation and intensity of the image. By regulating gain, you can brighten or darken the image so that in all respects it looks good going on tape.

ASTRONOMY: The color corrector is the key to avoiding purple-colored Saturns?

BREWER: That's right. After passing through the color corrector, the signal goes into an in-line image enhancer. This is another "black box" available from professional video suppliers that effectively makes the image overlap itself. This minute image shifting heightens the contrast and brings out the maximum amount of detail possible. The enhanced signal then passes into a video amplifier.

ASTRONOMY: What does the amplification do?

BREWER: The video amplifier is essentially your operations control center. You can hook up additional monitors or recorders to the amplifier. You can make tapes for friends while you are recording yours. You can also control the voltage of the signal, permitting further enhancement for detail. You must be careful with this, however. Sometimes the tape is not able to withstand the voltage saturation on bright objects and you end up "burning out" the tape the same way you overexpose film.

When you're done playing with the image, you simply record using the amplifier. At this stage you're producing an actual tape that will go into your video archives.

ASTRONOMY: Clearly video astronomy works best with very bright objects like the Moon and planets. Can you record deep-sky objects or comets with the system you currently use?

BREWER: No. In video, the critical limiting factor is the surface brightness of the object you're shooting. As an example, portions of the Orion Nebula are effectively bits of 4th- and 5th-magnitude light, but the nebula's average surface brightness is much fainter than that. At present, faint, extended objects are best recorded with other means, such as photography with standard films or sketching with pad and paper.

As far as stars go, I can usually record them as faint as 9th or 10th magnitude, depending on sky darkness and transparency. I can't say that I've ever recorded a star below 11th magnitude. Using a chart of the brightest stars in the Pleiades cluster as a reference, I've determined that some tapes I've made show the 9th-magnitude stars 117 and 203 Tauri. On a better night, however, I imaged an 11th-magnitude star near Zeta Orionis.

ASTRONOMY: What's ahead for video astronomy?

BREWER: I foresee a time when the widespread availability of video systems will make this technology an integral part of backyard observing. I'm sure that camera technology will improve to the point where faint objects like galaxies and nebulae will become part of video astronomy's domain. I hope that in the near future amateurs will use video astronomy to record and view observations, and teachers will explore the explosive potential that video astronomy offers to science education. In the meantime, I'll be outside shooting just a few more tapes. . . . ☐

M. Barlow Pepin edits The Reflector, *the newsletter of the Astronomical League, the largest federation of astronomical societies in the United States.*

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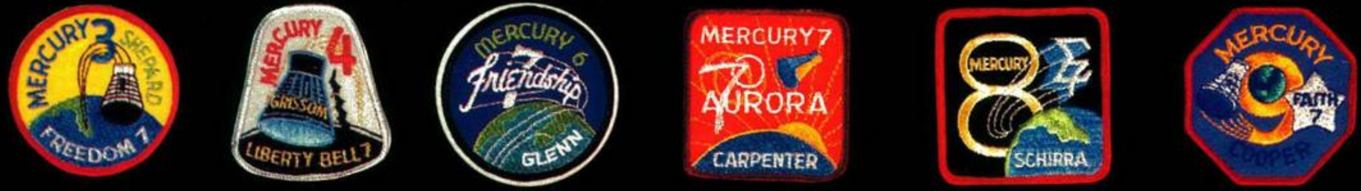
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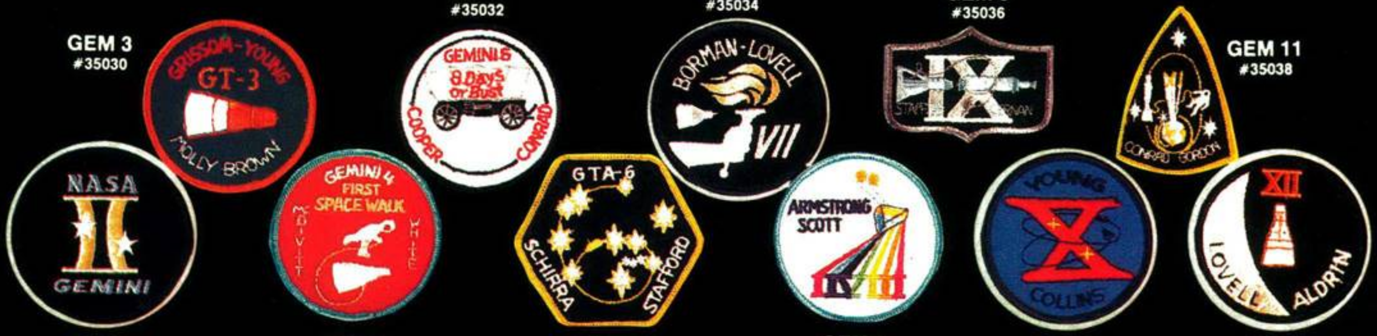
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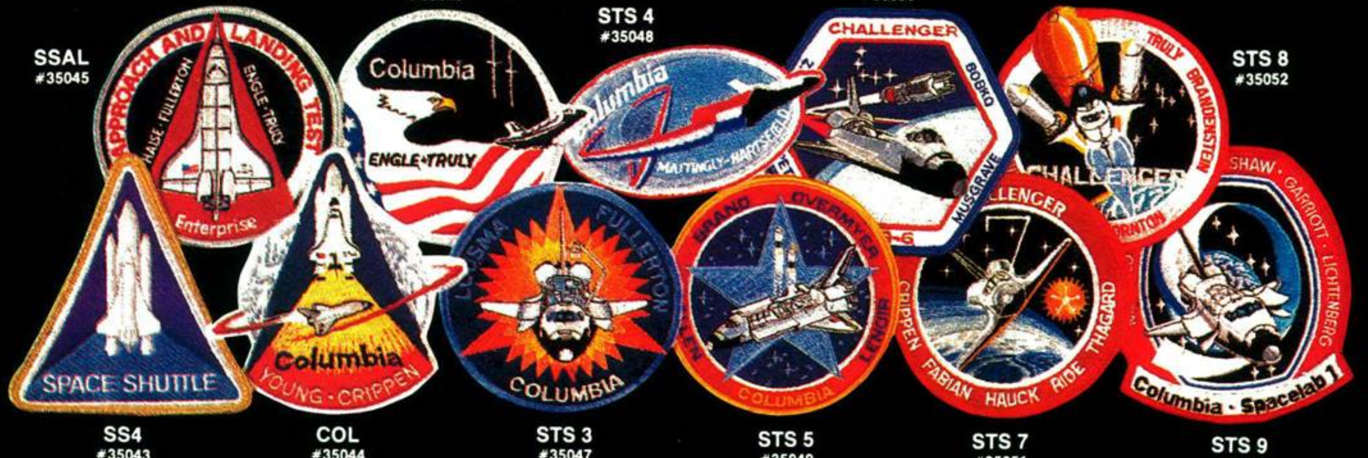
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THE SKY FROM NEW ZEALAND

"New Zealanders love their birds," related Candace Pratt of Harrisonburg, West Virginia. "New Zealand holds numerous species, including many not found elsewhere. On a recent trip to New Zealand, I enjoyed their birds but I *really* fell in love with their sky.

"Astronomy is no different than any other hobby," said Pratt. "The people make it enjoyable. My fondest memories of the three-week trip are the nights spent under the southern Milky Way. Before going I had devoted several weeks to learning the southern constellations. After arriving in Auckland, I felt ready for the test. My primary instrument was a 2.5-inch telescope made from a copier lens, constructed by my son as a Cub Scout project. He graciously loaned it to me after I rented a Nintendo game for him — fair deal. Astonishingly, the sky was so dark that the little telescope's images seemed like those from a much larger telescope.

"The first hour I spent under the southern sky left a lasting impression on my mind," said Pratt. "I set up my scope in a small campground in the middle of the northern island. A bicyclist from Alberta, Canada, set up nearby and came over to tell me that he subscribed to ASTRONOMY but had never looked through a telescope. Could he join me? Together we saw for the first time such wonders as 47 Tucanae, Omega Centauri, the Jewel Box Cluster, the Coalsack in Crux, and the Magellanic Clouds. After some time, stray cows wandered into the field we were using, but our 'oohs' and 'aahs' from the views overpowered the 'moos.'

"My second observing session occurred on the southern island," Pratt continued. "I set up the telescope near a small inn 2,000 feet above the valley floor and had a wonderful time scanning the unfamiliar sky. Unfortunately, I hadn't known that a local hunter fancied hunting rabbits on the land. At 1 a.m. he brought his jeep through, shots ringing out in the near-darkness. He passed me and took a hard look at the telescope as he waved in what appeared to be partial embarrassment. Needless to say, I abandoned that site.

"Following that night," said Pratt, "I boldly contacted the Mount Johns Observatory in the center of the southern island. With typical New Zealand hospitality, the superintendent gave me a tour of the facility and explained their work on searching for brown dwarfs and planets orbiting other stars. Afterward, I set up in

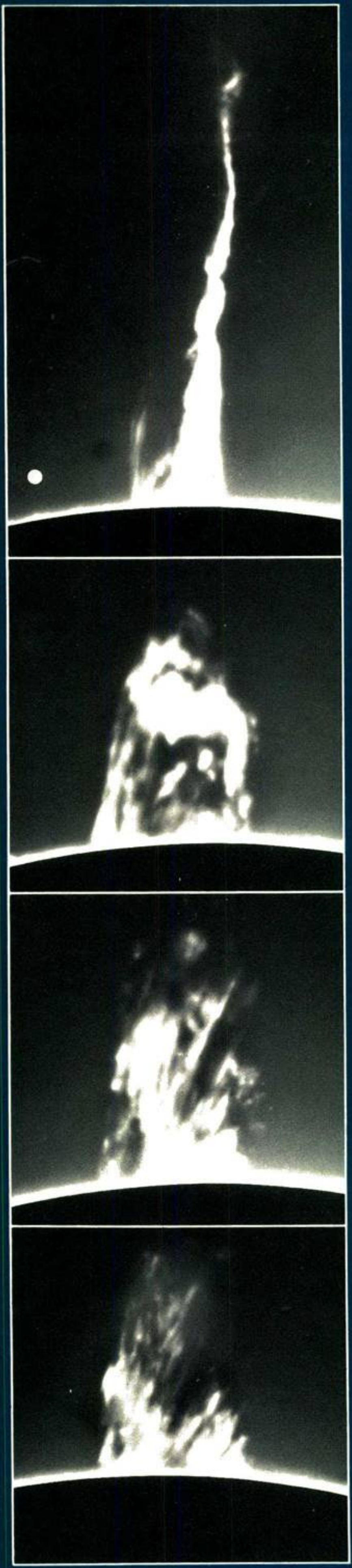
ORION TRAILS light the sky in an unguided, camera-and-tripod photo by Candace Pratt.

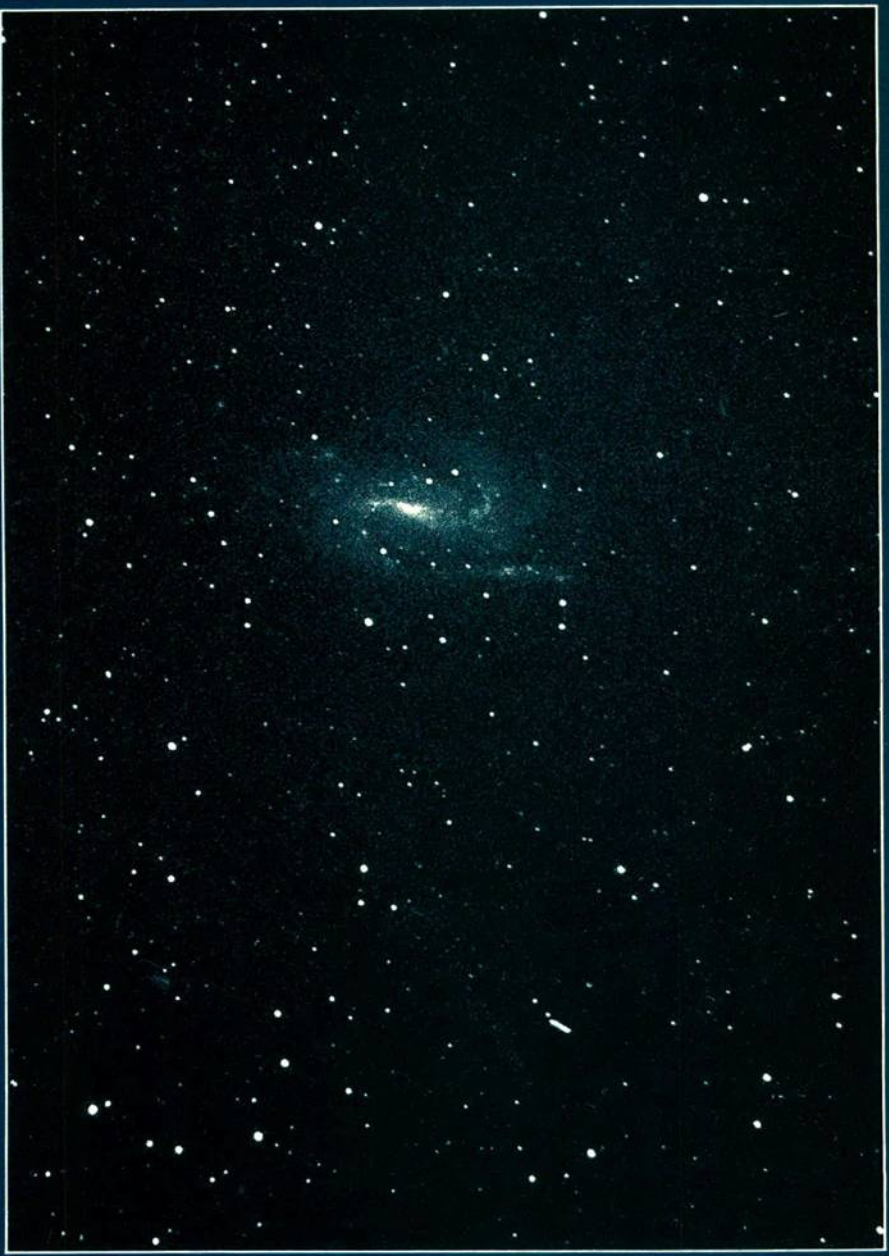
AURORA AUSTRALIS looms over central New Zealand in a camera-and-tripod photo by Candace Pratt.

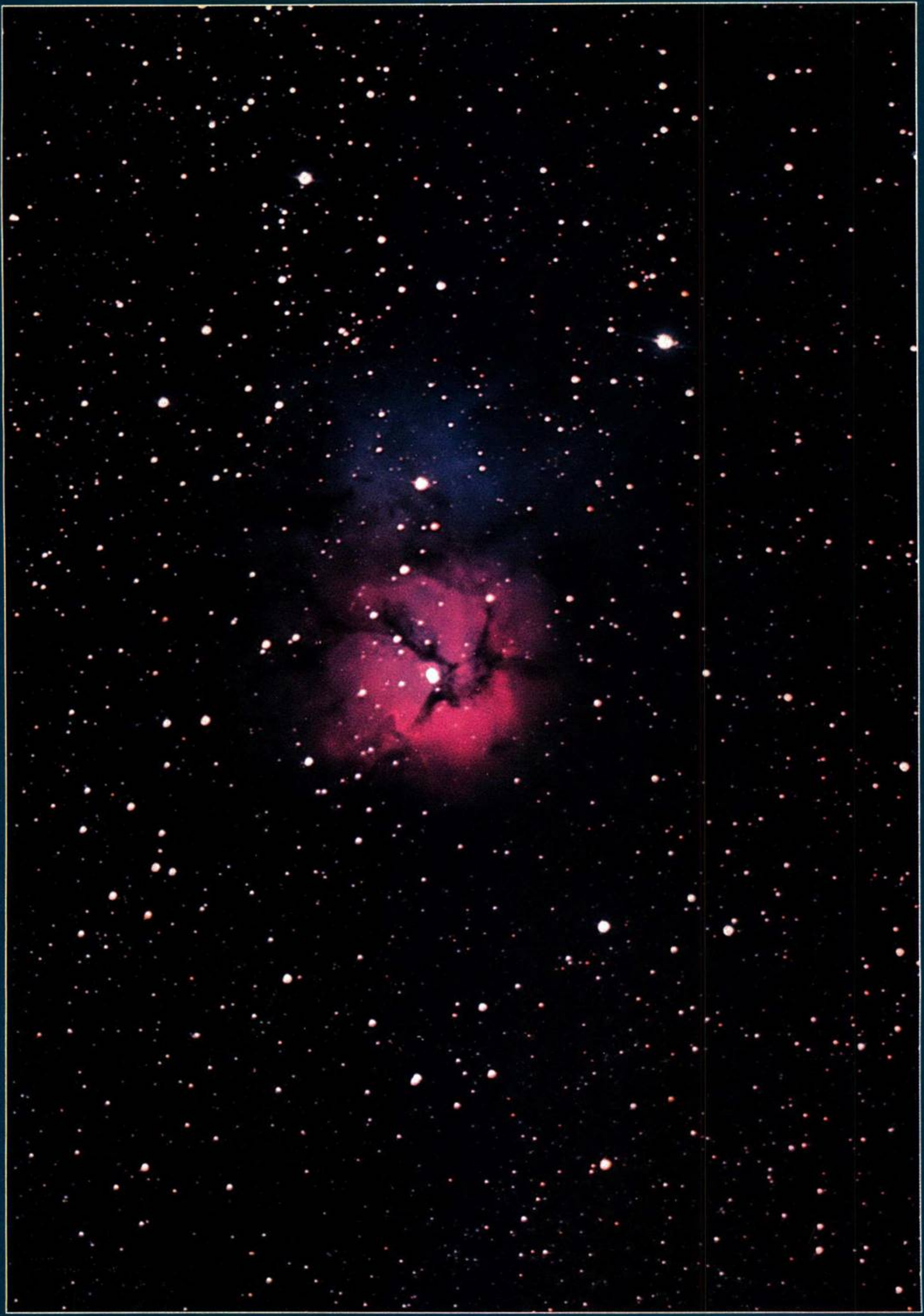
PASSING OF THE ASTEROIDS

Following the close approach to Earth of asteroid 1989 FC last March, several readers sent photographs showing faint asteroids passing by other denizens of the universe. This month's $100 "Best Astrophoto" award goes to Bill and Sally Fletcher's shot of the Trifid Nebula (M20) in Sagittarius (opposite page). In addition to showing the nebula, the 43-minute exposure reveals the streak left by asteroid 870 Manto on August 13, 1988. (It is visible 83 millimeters above and 16 millimeters to the left of M20's central star.) The Fletchers used a 16-inch f/4.5 reflector and hypered Konica 400 film. Preston S. Justis' photo of NGC 925 in Triangulum (bottom) captured the telltale streak left by asteroid 54 Alexandra on October 13/14, 1988. Justis used a 10-inch f/6 reflector, 103a-O film, and a 70-minute exposure.

Jean Dragesco's sequence of an eruptive prominence on April 23 (left) shows recent activity on the Sun. Dragesco used a 14-inch f/11 SCT, Tech Pan film, and a Daystar 0.6-angstrom H-alpha filter. The photo at the top shows the prominence at a maximum height of 195,000 miles at 8h07m UT. (The small white dot represents the size of Earth.) Successive photos show the prominence at 9h47m, 10h00m, and 10h10m UT.







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A GEMINID ZIPS THROUGH ORION last December 12 in this 3-minute exposure on Ektachrome P800/1600. Jerry Schad used an 85mm f/1.4 lens and developed the film at ISO 1600.

the observatory's parking lot and again enjoyed viewing the southern sky. As if that weren't enough, a magnificent display of aurora australis loomed overhead. I felt extremely lucky to have experienced such an adventurous introduction to the southern sky."

SEEING ALL THE PLANETS IN ONE NIGHT

"I didn't think it could be done," said Alex Scholten of the city of Eerbeek in the Netherlands. "But I did it. On May 7, 1989, I observed all the planets in a single night. First, I sought Venus in the evening twilight not more than 9° from the Sun. Although there were some cirrus clouds in the west, I spotted Venus with 15x80 binoculars.

"Jupiter, Mars, and Mercury were much easier to find," said Scholten. "With my 4-inch reflector I spotted the four Galilean satellites of Jupiter, and I also paused to view the Moon." In contrast to the bright planets, Scholten found Pluto a very challenging object. "It was visible only as a magnitude 13.6 'star'," he said, "requiring the 12-inch reflector at the Bussloo Public Observatory."

After a mid-evening rest, Scholten resumed searching in the early morning. "Saturn was clearly visible above the southeastern horizon, and Uranus and Neptune were nearby," he said. "To cap things off, I even looked at the asteroid Vesta. In less than six hours, I had observed all the planets, the six brightest moons, and the brightest asteroid."

SPRINGTIME METEOR REPORTS

Spring's meteor showers brought a flurry of reports of bright meteors from observers who watched the sky at the right time. One of the finest showers was the spring Lyrid shower, which peaked on the night of April 20/21. Despite the Moon's presence, on April 20 Michael Boschat of Halifax, Nova Scotia, recorded twenty-five meteors between 9 p.m. and 11 p.m. atlantic standard time. Most of the meteors were very bright, the average shining at −1 magnitude. "The most peculiar meteor," said Boschat, "was a +1 magnitude point meteor that appeared similar to M13. It appeared for two seconds and vanished." Point meteors are

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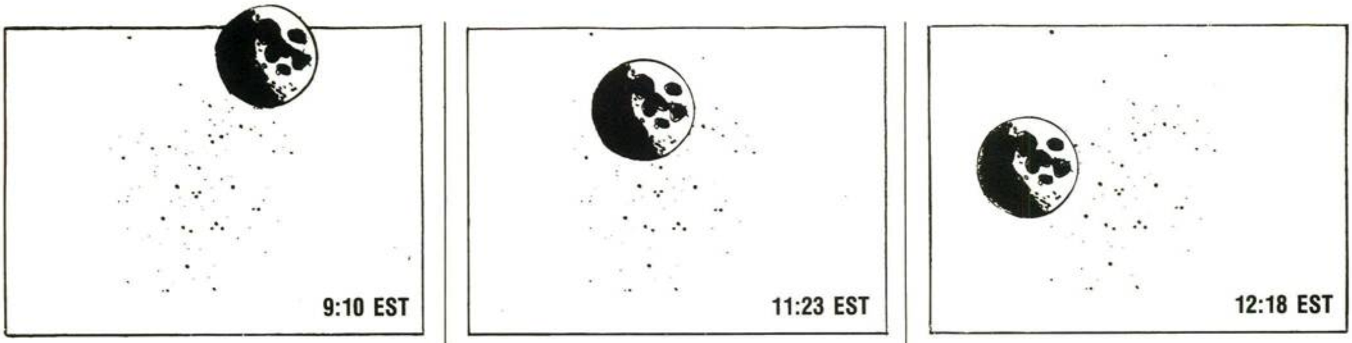

THE MOON BLOCKS the Beehive on the night of April 13, 1989. Larry McHenry recorded the event with a 3-inch f/12 refractor at 41x.

meteors that appear to move straight toward the observer, thus leaving a fuzzy point rather than a trail.

During the first few days of May the annual Eta Aquarid meteor shower peaked in activity. Boschat observed on May 3/4 and May 4/5 from Halifax. On the first night he reported that two Eta Aquarids attained 4th magnitude and displayed a distinctly greenish color. Their trains lasted approximately two seconds. On May 4/5, Boschat spotted thirty-two meteors over a one-hour period.

Observing on May 3/4, George W. Gliba of Greenbelt, Maryland, recorded five bright Eta Aquarids. "During a one-hour period on the morning of May 4," Gliba reported, "I saw five meteors that seemed to appear in two groups separated by a few minutes. Two meteors appeared within a few seconds, and several minutes later I saw three more appear within several seconds of one another. In addition to these, I observed six sporadic meteors."

THE MOON OCCULTS THE BEEHIVE

On April 14, 1989, the Moon passed in front of the Beehive star cluster (M44) in Cancer. Larry McHenry of Jeffersontown, Kentucky, sketched the event using his 3-inch f/12 refractor at 41x. "I devised an observing form before the event," explained McHenry. "I sketched the cluster and the Moon at its current phase and photocopied them, yielding a stack of cluster sketches and cut-out Moons. During the occultation, I recorded the positions of the Moon's disk as it moved in front of the cluster's stars. Afterward, I pasted the Moons down on the sketches.

"The occultation was somewhat difficult to observe," McHenry reported. "The stars in M44 are pretty faint, and the Moon's glare made the faintest stars disappear as the glare came near them. Despite this, the M44 occultation was exciting to watch, and I am looking forward to seeing it happen again." — *David J. Eicher* ☐

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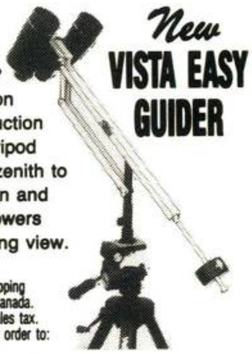

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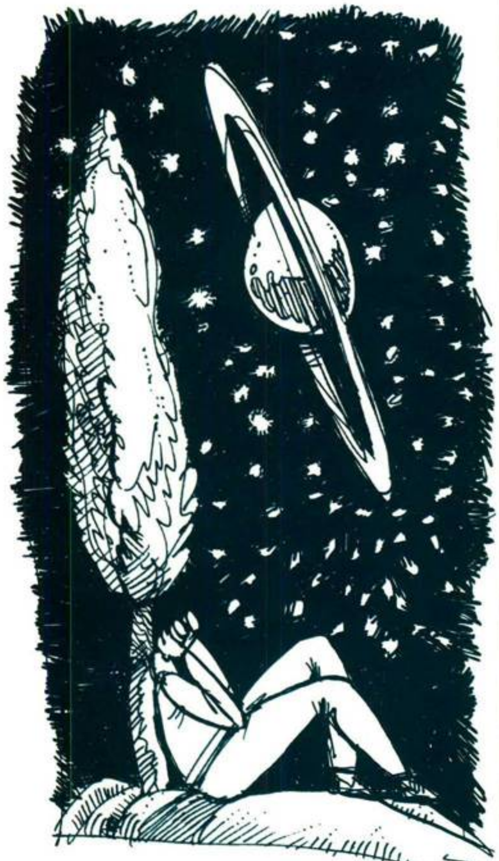
MR. KILLORAN'S FIFTH-GRADE COSMOS

Up until the time I was ten years old, I never cared about the sky. That changed in September 1965, when I landed in Mr. Killoran's fifth-grade class at Chappell Elementary School in Green Bay, Wisconsin. It was not an association I looked forward to. According to the word on the playground, Mr. Killoran was a teacher to be feared. Short, balding, gruff, and proudly Irish, Mr. Killoran was known to bark loudly at his students; and if you didn't cut the mustard, a guy ended up in "Stalag 13," Mr. Killoran's term for staying after school.



I spent many autumn afternoons during the first half of that school year watching the janitor sweep our room. Mr. Killoran and I weren't clicking, and it showed on my midterm report card. "This student is a major disappointment," he wrote on my report card. When you lug literature like that home to your parents, you take your time getting there.

At my parents urging, I started the second half of the school year with an enlightened attitude. The first science unit of the semester began with astronomy. Mr. Killoran introduced us to the planets, stars, constellations, and a wonderful film called "Our Mr. Sun," which he let us watch twice in one day.

One day, he showed us how to properly hold binoculars in order to see the moons of Jupiter ("Sit against a tree or a house, legs up, elbows resting on the knees so you create a make-shift bipod for the binoculars, like this.") Slowly, Mr. Killoran was evolving from nemesis to nice guy. He became someone I looked forward to learning from.

That winter, I read every book on astronomy I could find in the school library. There were two books I grew to love. One was called *The Sky Observers Guide* and the other was a little handbook called *Stars*. They were masterpieces. I yearned to see the planets the way these books pictured them and I wanted to explore all the activities that were suggested in those classics. But I needed optical aid.

I saved my dish-wiping money and sent for my first telescope. It was a scope advertised in the back of a *Spider Man* comic book. It cost $4.95, was 430x, and took six to eight weeks for delivery. I figured it would take me right to Jupiter's Great Red Spot.

Finally, my 30mm refractor arrived. Upon opening the box, I was perplexed by the plastic lenses and flimsy cardboard tubes. After I assembled this long-awaited telescope and tested it out on a distant house, I saw every color in the rainbow. I suspected all those dishes had been dried in vain.

Before I knew it, January became June, and my fifth-grade year had ended. I sprinted home with my report card this time. Mr. Killoran's remarks summed up my new interest in the world around me. "Ever since the unit on the sky, this boy has really come along." An enthusiastic teacher, coupled with sensational subject matter, had turned my boat around.

During the summer, I visited the public library and checked out an arm load of astronomy books each week. I borrowed the latest edition of the Edmund Scientific catalog from a friend and spent the better part of that summer gawking. The telescopes in that thin publication were the targets of all my boyhood fantasies. I was astounded at Edmund's 8-inch reflecting telescope. It looked so fat! It was loaded: rack-and-pinion focuser, equatorial mount, clock drive. At $389.95, I knew my parents couldn't afford it, but it became the stuff of my dreams. Through the window of my imagination, I visited every astronomical marvel with it.

But I had to set my sights lower. Edmund's 3-inch reflector was $29.95. With a strong back and a dependable lawn mower, I went to work and by early August I was again playing the waiting game. When I saw the postman bringing that long box to our door, I became the happiest boy in America. Although the 3-inch mirror was somewhat limiting, I saw everything our light-polluted skies would allow.

It's been twenty-two years since fifth grade, and my boyhood dream of becoming a professional astronomer never came to be. I didn't take the career path I plotted out during the summer of 1966. Astronomy has become only an occasional adult pastime. I don't brave the chill of winter nights to estimate Cepheid variables, and I can't say that I've spent every day of my life thinking about our celestial existence.

But when I do, it's like meeting an old friend again. There are times when that old friendship recreates the magic I first felt when I was told of the stars.

The recent partial solar eclipse in March rekindled that wonder again. Although only 15 percent of the Sun was blocked from my spot on Earth, I was still amazed at the beauty of eclipses.

Watching the eclipse, I wondered if Mr. Killoran had another fifth-grade class outside looking at the Sun's projected image. Was some young lad in Mr. Killoran's class discovering for the first time how fascinating this science could be? I'd bet on it. — *Roger Dier*

THE PRIZE IN THE SKY

It started out innocently enough during dinner. I asked April, my nine-year-old daughter, if she would like to go to the Messier Marathon that my astronomy club, the Ventura County Astronomical Society, was sponsoring. "Gee Dad, that would be fun. Sure, you bet!"

I was elated. My wife was shocked. My wife's definition of "roughing it" is getting a room with a view at the Hilton on the wharf in San Francisco, and she was hoping April would grow up with the same *refined tastes*.

"But April," my wife warned, "you'll have to sleep outside or in the car."

"No sweat, Mom, we'll get a sleeping

bag,'' my daughter told her.

''What will you eat?'' my wife wondered out loud.

''We'll take a cooler with sandwiches and bring a thermos,'' both April and I chimed.

My wife thought for a moment and then her face lit up with a mischievous smile. She thought she had the argument that would quash this silliness of going into the boondocks.

''April,'' she said softly, ''there are no flush toilets where you're going.''

April looked like she had accidentally swallowed a bug. She shot me an accusing look. ''Daaaaad!''

Well, there we were, April looking at me with the frown of a judge at an Inquisition, my wife with a serene look of triumph, and me. I had the look of a toad who tried to catch a moth flying around a light bulb, only to get a burnt tongue.

Looking at April again, I noticed the alarm had subsided. ''They have those toilets like they had at the air show last summer,'' I ventured. April weighed that bit of information for a second and said resolutely, ''Okay, Dad, let's go.''

I spent the next week or so making a list of things we needed to buy or borrow. You see, I've never been camping before or even gone to a star party. Yes, I know I'm the treasurer of the astronomy club, but that doesn't mean I'm one of those ''macho astronomers'' who knows all the NGC objects, spends every night looking for comets, and braves cold, hunger, and sleep deprivation to take astrophotos.

The Saturday of the contest, I packed in a frenzy and got the car loaded. April made sure all her essential things were in the car, too: her sleeping bag, her favorite comforter, thermal underwear, cassette player, books, granola bars, cookies, and . . . ''Don't forget the hot chocolate, Dad!''

We got to Saddleback Butte just before sundown. There were about thirty of us there. Everyone was getting their scopes ready so they could start by the first starlight. Dusk settled down and we all went to our scopes.

Some of the serious contenders went to work right away while others observed Venus and the thin crescent Moon. It seemed that most of us had a plan to win the contest. Some people came the previous night to practice. Others had their own secret observing itinerary. My plan was to try not to appear totally ignorant and not take the competition too seriously.

There was quite a mix of telescopes at the site. Sizes varied from a 17.5-inch Dobsonian and a 14-inch SCT to a small refractor. The peripheral equipment brought along varied as much as the scopes. It was also interesting to hear the variety of music people were listening to. Some of them listened to Holst's ''The Planets'' or ''Star Wars'' themes to get them into the mood, others preferred golden oldies.

The first few hours passed and everyone was in good spirits, despite the dropping temperatures. I had found about ten objects, many for the first time, and felt pretty good, so I visited other people. Though there was a contest going on, everyone had time to talk and people were helping each other.

When some of the serious contestants had over fifty objects, I decided I had better get into high gear. April read the coordinates to me as I used setting circles to get around. I didn't know my way around well enough to star-hop, and without an AC inverter the going was slow. I became very familiar with the coordinates of stars like Regulus and Arcturus, using them to set my hour circle before going on to the next object.

April, like the other kids, had a good time. She thought it was neat to walk in the dark, stay up late, and drink hot chocolate under the stars. She also enjoyed looking at many of the new objects I had found and felt good about helping Dad.

Around 1:00 a.m. we started to lose some people as they got cold or tired. April was up until 2:30, long after many of the grown-ups had retired.

I was doing okay until I got to the objects in the Virgo cluster. It took me a long time to figure out which one was which. I finally managed to get out of that part of the sky and started to make real progress until dawn.

Most of the contestants did very well. That night, two people observed 110 objects and many others logged over a hundred. It seems to me that people are getting so good at this type of competition that we may need a time clock to determine winners next time. I wound up with only fifty objects, but I was still happy. Most of the fifty I had never seen before.

No, I wasn't disappointed about finding only half as many objects as others did. The value of entering a contest like this is that it's a learning experience. The pressure to succeed and do well pushes you to learn things and remember them better than you normally would. The next night I easily found many of the objects I had never been able to find before. I'm happy that I made many new acquaintances in the sky that I can now call my friends. — *Michael Chibnik* ☐

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LUNAR GUIDE BADLY FLAWED

The Moon Observer's Handbook by Fred W. Price, (Cambridge University Press, 1989), ISBN 0-521-33500-0, hardcover, 309 pages, $34.50.

The Moon Observer's Handbook has a strange feel to it. Although copyrighted in 1989, it largely reads as if it was written in the 1950s. Because it bears the imprint of Cambridge University Press, many potential buyers will assume it contains current lunar knowledge. I only wish it did.

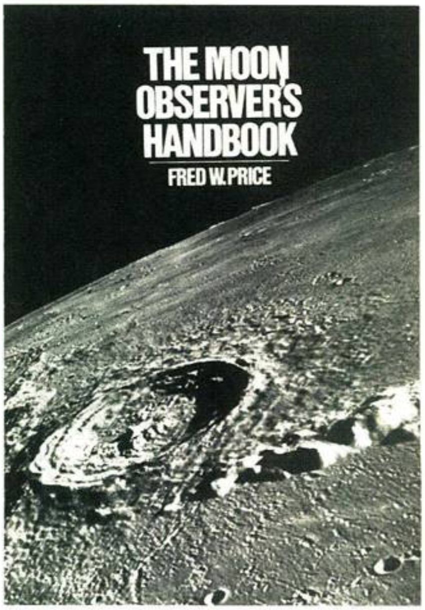
Fred Price teaches biology at State University College in Buffalo, New York, and has been a lunar observer for twenty-five years. His book starts with an excellent introduction titled "Why Observe the Moon?" He answers the question in a way few could improve on: "To come home after a tiring day and view the silvery crescent of a 3-day-old Moon on a spring evening is wonderfully relaxing and enjoyable."

However, the first chapter, "Our Moon," will surprise many knowledgeable readers. Price's outline of lunar geography ignores established convention regarding lunar east and west. His Mare Crisium lies on the western half of the Moon rather than the now-standard east. This agrees with pre-space age books and maps but is completely out of step with all recent work. More disturbing, Price uses terms such as *lunabase* and *lunarite* (for the maria and highlands) that became obsolete over two decades ago. Finally, his bibliography runs heavy on outdated or crank books.

Chapter two on the Moon's motions is good, though perhaps it might have been omitted because many backyard Moonwatchers already know about phases and eclipses. Chapter three on telescopes goes somewhat off-track and in a few places is seriously misinformed. Its basic assumption seems to be that the reader will decide to observe the Moon before having any experience with a telescope, whereas I suspect most people today rush out and buy a general-purpose telescope long before they become lunar observers. On the misinformation side, the refractor market is no longer limited to long focal-ratio achromats, and eyepiece design has progressed well beyond orthoscopics. (Price mentions Plossls and Naglers, but dismissively.)

Chapter four follows the Moon's features from New to Full. It is a factual description of features written from Price's observations and also drawing liberally on published accounts by Neison, Elger, Goodacre, and Wilkins and Moore — all the "greats" of pre-1960 lunar observing.

It is bothersome, however, to find Price discussing the existence of one feature or another by summing up what the old-time authors said about it. He is missing an important point: whether or not a feature exists can be settled quickly by a look at the relevant spacecraft photos from lunar orbit. Today's amateur astronomer doesn't need a rehash of old debates about features seen from Earth, but a book that joins Apollo's revelations to the view in a backyard telescope. A much more valuable book would be one that lets you explore the Moon with a knowing, telescopic eye and shows relationships among features that have real geologic meaning. Price never achieves this, although the requisite information has been available for most of the past decade.



All through chapter four drifts a timeless sense that the entire lunar program never happened. Indeed, Price often seems to be regathering clouds of mystery over a landscape whose geography was established twenty years ago. He discards the work of a generation of professional lunar scientists for the sake of creating a cozy, anything-can-still-be-true atmosphere *in which amateur observations are once* again valuable.

Price's attraction to lunar studies of the 1950s is somewhat understandable. The

1950s were wonderful for amateur lunar observers — good telescopes were widely available and an army of professionals hadn't yet invaded the turf. (In fact, many amateur lunar observers of the 1950s went on to become that army in the 1960s.) But those days are gone for good, and books that ignore Apollo can't bring them back.

Chapter five covers observing and recording what you see; it's really the best chapter in the book. Price clearly has spent a lot of time at the telescope and gives excellent advice on atmospheric seeing, magnifications to use, how to make sketches, and so on. If the rest of the book held to this standard, I'd recommend it enthusiastically.

Chapter six deals with "Mysterious Happenings on the Moon." Besides retelling the famous Linne case, Price explores many other features that (until the space age) were suspected of changing. The stories are intriguing, but with the exception of transient lunar phenomena (TLPs) few if any of the cases are alive today.

The last chapter, called "Suggestions for Research," must have been hard to write because professional planetary science has little use for backyard Moon observers. Price recommends, among other projects, observing the "Luna Incognita" region near the south pole (missed by orbital photography), hunting for TLPs, and tracing ray systems at high Sun angles. Whatever their ultimate value to professional astronomers, engaging in such projects certainly makes you a sharper observer.

Where did this book go wrong? Its central flaw is that the author has ignored virtually all professional work in lunar geology of the last twenty-five years. For example, Price thoroughly misleads his readers right from the beginning by claiming that the impact theory of crater origins has "serious objections to it on theoretical and observational grounds."

This stance was perhaps defensible throughout the 1950s, although Ralph Baldwin's *The Face of the Moon* had made an excellent case for impact in 1949. But after Gene Shoemaker and Robert Hackman's paper on the stratigraphy of the Copernicus region (1962) and Baldwin's *The Measure of the Moon* (1963), most lunar geologists knew that impact was the key process in forming craters and shaping the surface.

Price doesn't tell you that from the biggest basins to microscopic "zap pits," craters are impact structures, although many have been modified by landslides, slumping, lava intrusions, and faulting. Moreover, any book on the Moon that denies a dominant role of impact is both wrong

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ANNOUNCEMENT – The Astronomical Society of Kansas City meets on the fourth Saturday of each month. Meetings begin at 7:30 p.m. in Room 103 of Royall Hall at the UMKC campus. For more information contact the ASKC, P.O. Box 400, Blue Springs, MO 64015 or phone Gary Pittman at (816) 228-4238.

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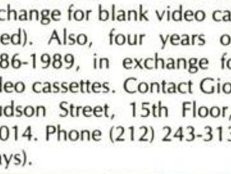

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and out of date — and not just by years, but by decades. (If you want the real story, look in a large library for Don Wilhelms' *The Geologic History of the Moon*, published in 1987 by the U.S. Geological Survey as Professional Paper #1348.)

Authors will be authors. The blame for this book's failures lies less on Price than on Cambridge University Press for not exerting stronger editorial control. For a reputable press to issue a work so seriously flawed prompts informed readers to wonder what's going on. — *Robert Burnham*

A COMPREHENSIVE, COLORFUL PHYSICS TEXT

The New Physics, edited by Paul Davies, (Cambridge University Press, 1989), ISBN 0521-30420-2, hardcover, 516 pages, $39.50

This expansive survey covers the developments in the unfolding field of modern physics. The contributor's list reads like a *Who's Who* of preeminent thinkers in quantum mechanics, physics, astrophysics, and cosmology. Contributors include Alan Guth and Paul Steinhardt ("The Inflationary Universe"); Stephen Hawking ("The Edge of Spacetime"); Frank Close ("The Quark Structure of Matter"); and Abdus Salam ("Overview of Particle Physics").

Thankfully, editor Davies preserved the varying writing styles of the authors. This not only enlivens the book's content but also varies the reader's response to each chapter, so the continuity doesn't flow like that of an homogenized textbook. And though some of the topics are quite technical, Davies wisely steers the authors away from overspecialization. Basic terms are defined, and jargon is kept to a minimum. For those readers whose desire to learn supersedes their intimidation with physics concepts, this book should pose no problem.

One of the longest and best chapters is "The New Astrophysics" by Malcolm S. Longair of England's Royal Observatory. In 115 pages, Longair manages to present a clear, in-depth report on all wavelengths of astrophysics today. Each section contains an amazing amount of up-to-date information, which is surprising given the burgeoning research in astrophysics and sluggish publishing schedules!

The New Physics also addresses recent developments in other fields of research. For example, if you have ever wondered what the "chaos" concept is and how it relates to the universe, Joseph Ford gives you his clever reply in "What Is Chaos, That We Should Be Mindful of It?"

The New Physics is amply illustrated with color drawings, graphs, and photographs. It also includes excellent reference sections at the end of each chapter. For readers who want to know about the latest happenings at the frontiers of physics from the leading authorities in the field, this book is a must. — *Jeff Kanipe*

ASTRONOMICAL DETECTIVE STORY

Interstellar Matters by Gerrit L. Verschuur, (Springer-Verlag, 1989), ISBN 0-387-96814, hardcover, 328 pages, $29.95.

Back at the turn of the century, the nature of interstellar matter, indeed its existence, eluded astronomers. Long-exposure photographs of rich regions of the Milky Way taken in the late 1800s revealed inky black regions in which few if any stars could be seen. Were these dark regions holes in the fabric of space, rended by star clusters or some other force, or vast clouds of dust obscuring background stars? Either way, the answer would have far reaching implications about the environment between the stars.

Verschuur's *Interstellar Matters* tells the story of how astronomers painstakingly pieced together observations and theories until they eventually came to recognize interstellar space for what it is: the breeding ground for stars.

The understanding that matter exists between the stars marks the emergence of modern astrophysics from astronomy. However, it wasn't a smooth transition; there were a number of wrong assumptions and uncertainties.

The book opens with the life and career of Edward E. Barnard (see "Barnard's Dark Dilemma" by Gerrit L. Verschuur, February 1989). A peerless observer and one of the pioneers of long-exposure astrophotography, Barnard never could quite decide if the dark gulfs between the stars that appeared in his photos were dark nebulae obscuring background stars or true holes in space.

Verschuur follows the winding track of interstellar-matter research from the debate over its existence to its ultimate acceptance. The second half of the book presents the modern aspects of interstellar studies and the exciting implications of recent discoveries, such as the mysterious "extreme scattering events," dark interstellar "scud" that temporarily blocks radio transmissions from quasars.

Interstellar Matters is a science history and a detective story in one enjoyable package. — *Jeff Kanipe* ☐

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GHOST LIGHTS IN THE SKY

Aurora, (Geophysical Institute, University of Alaska, Fairbanks, AK 99775), 27 minutes, color, $29.95 (plus $3 shipping), VHS or Beta.

What backyard astronomer hasn't been startled, and then thrilled, by the pale flickerings of an aurora? The aurora borealis is visible mainly north of about 45° north latitude, but during years of high solar activity (such as now) even observers across the southern United States may get a taste of this ghostly sight, as many discovered this past March.

I don't know about you, but when I see a full-blown aurora, it's *spooky*. Those huge curtains in the sky are beautiful, all right. But they're also big, and they're moving, and the whole experience is often a little frightening. Maybe they trip some primitive response way down in the midbrain, or maybe they echo some almost-forgotten vision of apocalypse; I can't say. But I do know that it's hard to completely escape a feeling that "something has gone terribly wrong with the world" when those pallid curtains and streaks begin to sway and pulsate in utter silence.

Aurora largely tames the beast. In the process of squeezing the phenomenon into The Tube, low-level anxiety is banished and replaced by plain wonder. The aurorae in the video, filmed during 1985 and 1986, are marvelous. You see curtains form, brighten in places, and die away. They move from one part of the sky to another. Rays take shape, arches form and vanish, knots twist and loosen. There's also a technological marvel at work here: even the brightest auroras are pretty dim, at least by ordinary video standards. Yet *Aurora* shows them in color — and even more startlingly, in real time — thanks to a recently developed high-sensitivity television camera.

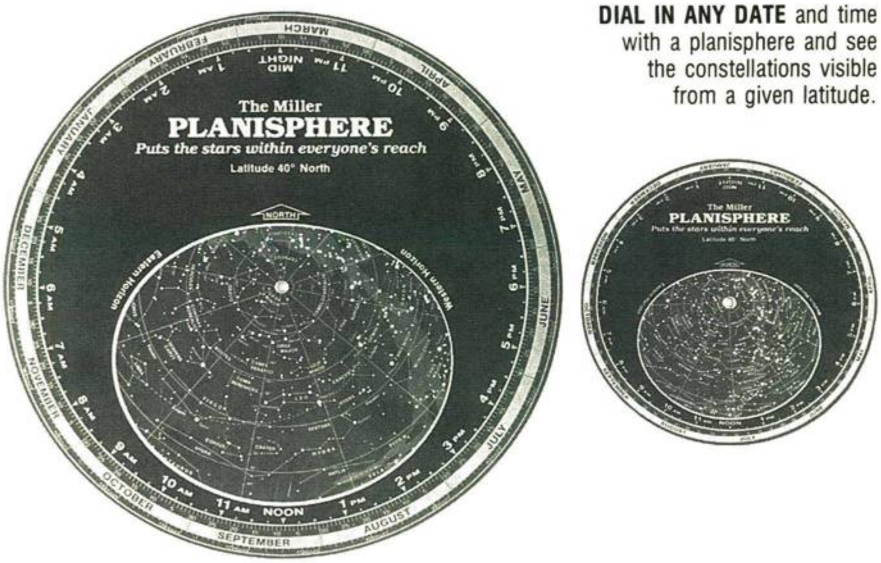
The video comes with a twenty-two-page booklet that tells you what causes the aurora, where to see it best (both borealis and australis), and the different forms it can take. The video has no commentary, but a pleasingly eerie musical soundtrack excerpted from the *Symphony in Ursa Major* by Gordon Wright, a composer at the University of Alaska.

It's a shame that most audiences of this fine video will probably see it only in a classroom, because it shows a simple, quiet, natural beauty that can best be enjoyed at home. — *Robert Burnham*

OBSERVING AIDS

Planispheres, (Northstar Imports, P.O. Box 60100-A, Reno, NV 89506), 5½ inch diameter, $3.95; 10½ inch, $7.50.

A planisphere portrays the sky for any date and time at a given latitude. These two planispheres are made of plastic and show white stars to 5th magnitude on a dark blue background. The Milky Way and grid lines of right ascension and declination are printed in gold. Tick marks around the rim of both planispheres represent each day of the year and time divisions at 15-minute intervals. The large planisphere also includes selected Messier objects and right ascension tick marks at 5-minute intervals.



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SPACEY MUSIC

And the Stars Go with You by Jonn Serrie, (Miramar Productions, P.O. Box 15661, Seattle, WA 98115, 1988), 40:07 minutes, CD, $15.98; cassette, $9.98.

Five tracks of synthesized space music provide pleasant, slightly above-average "easy listening" in the now well-worn New Age idiom. Serrie says the music is "a tribute to the triumphs and infrequent setbacks in the space program." He dedicates the record to Christa McAuliffe, the school teacher who died with the rest of the *Challenger* crew in 1986.

SPACE VIDEOCY

Space Music, (Malibu Video, 22653 Pacific Coast Highway, Suite 146, Malibu, CA 90265), 52 minutes, color, $19.95 (VHS, Beta); $24.95 (super VHS).

Space Music is made up of three separate and unrelated video segments: "The Race for Space" (a documentary on the U.S. space program); "In the Beginning" (Genesis, chapter 1, read by the *Apollo 8* crew in lunar orbit); and "Starflight" (a simulated voyage out of the solar system toward Alpha Centauri). It also includes a twenty-minute documentary called "The Making of *Space Music*."

"Race" lasts about nine minutes and is woven together from short clips from the Mercury, Gemini, Apollo, and shuttle programs. In place of narration, we get a loud soundtrack that sounds like a cross between *Spartacus* and *2001*. The bombast might be bearable if the visuals told a coherent story, but they don't. While many of the clips are interesting when taken individually, chronology apparently meant nothing to the video editor because one clip follows another with only the loosest regard to historical sequence. This totally undermines the video's stated intent: "document[ing] the American space program from the first suborbital flight of Alan Shepard to the final blast-off from the Moon by the crew of Apollo 17!"

"Beginning" runs about three minutes and is presented with fewer cutting room shenanigans, largely as the astronauts recorded it on Christmas Eve, 1968.

"Starflight" (twenty minutes) was a clever idea, but its execution is so lamebrained that it will send you into hoots of laughter. The year is 2026 and a manned interstellar spacecraft is being launched toward Alpha Centauri. The trouble is, the path out of the solar system followed by the craft is that of *Voyager 2*. The video reuses the now-familiar JPL animation of each *Voyager* planetary encounter and pretends this is what the crew is seeing. Nor do we get much of a look at starflight itself: perhaps because the creators of the video didn't dare go where JPL's computers hadn't boldly gone already, the craft "loses navigation lock" in hyperspace beyond Neptune and the crew dies in some unspecified way.

Besides the fact that *Voyager 2* isn't headed anywhere near Alpha Centauri, the video creators either don't know or don't care that the planets won't be in those positions in 2026 — or maybe they figured the audience was too dumb to notice anyway.

With only one hit out of three (or four, if you count the "Making" segment), *Space Music* offers a pretty thin value for the money. — *Robert Burnham*

PULSAR HISTORY TAPE

The Discovery of the Pulsar, (BBC Cassettes; distributed by the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112), 1-hour audio tape cassette, $13.95.

The discovery of the first pulsar in 1967 was one of the most dramatic and important astronomical findings of the last fifty years. In this tape, prepared from a BBC radio program, the story of the discovery is retold by the two principal scientists involved: Anthony Hewish, whose radio telescope detected the pulsar's signal, and Jocelyn Bell (now Bell-Burnell), who, as Hewish's grad student, was the first person to notice the signal on the telescope's chart recorder output and recognize that it came from a celestial source.

Although the signals were first recorded in August 1967, Hewish, Bell, and their collaborators didn't announce the discovery until February 1968, largely because they had trouble convincing themselves that they had found a natural astronomical object — and not, for instance, manmade interference or even signals from an alien civilization (which was considered, and ruled out). The tape does a fine job of putting into perspective the months when the team was struggling to understand what they had found and the eventual emergence of the spinning neutron star explanation.

The second side of the tape contains a popular lecture titled *Ultimate Ignorance* by astrophysicist Paul Davies that covers black holes, Big Bang cosmology, and the ultimate fate of the universe. The lecture is clear and interesting enough, but I would base any purchase decision on the Hewish/Bell-Burnell story alone, which is well worth having. After all, how often can you get the inside story on a major astronomical discovery directly from the people involved? — *Robert Burnham* ☐

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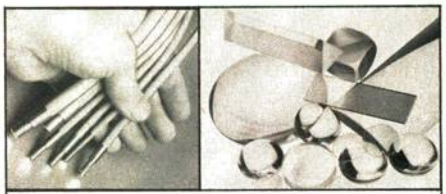

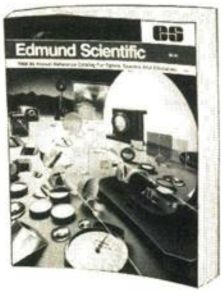

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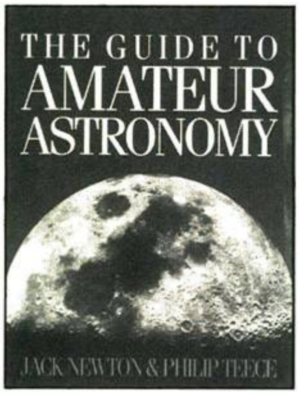

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Contact Karl Fabian, 3123 North Kenneth Avenue, Chicago, IL 60641. Phone (312) 777-3226.

WANTED – Observations of Martian canals or canal-like markings from the 1988 or any previous opposition of Mars. Contact Dennis Sopchack, 2 Aluminum City Terrace, New Kensington, PA 15068. Phone (412) 337-0509.

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WANTED – Jaegers 6″ f/8 tube assembly or lens/cell assembly. State price and condition. Contact Brian P. Beirne, 7822 Stuart Ave., Montreal, Quebec, Canada H3N 2R6. Phone (514) 272-0066.

WANTED – Correspondence with Oriental amateur astronomers who are interested in old and modern astronomy, especially the ancient Chinese astronomy. Also, an interest in manned and unmanned space flights. Contact Wayne Scott, Number R10724, B. Wing, H.M. Prison, 5 Love Lane, Wakefield, England WF2 9AG.

WANTED – Fourteen year old seeks correspondence with persons worldwide interested in astronomy using telescopes, binoculars, or the naked eye. Contact Simon Lau, 2 Drumcliff Avenue, Killarney Heights, N.S.W. 2087, AUSTRALIA.

WANTED – Correspondence with anyone regarding space colonization, the meaning of *2001: A Space Odyssey*, astronomy in general, cosmology in particular, and the potential impact of fusion energy on our society. Contact David Lyttle, 2719 Della Drive, Dayton, OH 45408.

ANNOUNCEMENT – The Texas Astronomical Society of Dallas meets the fourth Friday of each month (except Dec.) at 8 p.m. in the auditorium of Scottish Rite Children's Hospital, 2222 Welborn. Programs consist of both professional and amateur presentations and slide shows. Contact TAS, P.O. Box 25162, Preston Station, Dallas, TX 75225. Phone (214) 248-7618.

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FOR TRADE – Parks 6″ f/8 parabolic mirror, purchased June 1988, for 6″ f/5 mirror. Contact Allen Ellefson, 233 Highway #1, Silver Bay, MN 55614. Phone (218) 353-7624 (evenings).

WANTED – Eighteen-year-old amateur astronomer seeks correspondence with other teens worldwide interested in astronomy or science-related subjects. Will reply to all letters. Contact Michael Brannan, 28442 Via Teresa, Laguna Niguel, CA 92656.

WANTED – Information on obtaining a 35mm camera mount for a Bushnell Banner Astro 400 telescope. Contact Tracy Spitulski, 1658 Idlewood Drive, Toledo, OH 43615.

WANTED – Celestron 8″ f/1.5 Schmidt camera, new or used, in good condition. Contact Tom Sorbel, 1200 Nicollet Avenue, #422, Minneapolis, MN 55403. Phone (612) 338-4306.

WANTED – Contact with anyone who has direct and full access to NASA photographic archives. Also, will buy or trade secondhand books on *Apollo*, *Gemini*, shuttle, historical, etc. Contact Ian Broadbent, 125 East Bawtry Road, Rotherham, South Yorkshire, England, S60 4LQ.

WANTED – Sixteen year old seeks correspondence with persons worldwide interested in astronomy. Contact David Beaumont, 4 Kitchener Street, Nedlands, 6009, Western Australia.

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WANTED – Fifteen-year-old amateur astronomer seeks correspondence with others worldwide. Will reply to all letters. Contact Ed Bruckner, 23 Norwood Road, Springfield, NJ 07081.

FOR SALE – Right ascension drive, spur gear, and dual motor. Like new. Original equipment on C8. $100 firm. Contact Vern Slichter, E 10913 19th, Spokane, WA 99206. Phone (509) 924-4074.

FOR SALE – Commemorative solid brass telescope with 40mm objective. Engraved "The Return of Halley's Comet 1985-1986." Traditional ship-style scope. $98. Contact Sid Rodriguez, 1734 North Springfield, Chicago, IL 60647.

Meetings and Events

August 23-27
Planetfest, Pasadena, California. *Voyager 2* at Neptune events sponsored by the Planetary Society. Contact: Susan Lendroth, 65 North Catalina Avenue, Pasadena, CA 91106. Phone: (818) 793-5100.

August 25-26
Starfest '89, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact: Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5.

August 25-27
3rd Annual Astronomy Rendezvous and Conference, Normal, Illinois. Sponsored by the Twin City Amateur Astronomers, Inc. Contact: Donald F. Johnson. Phone: (309) 452-3866.

August 25-28
Nova East '89, Fundy National Park, New Brunswick. Sponsored by the Royal Astronomical Society of Canada-Halifax Centre. Contact: Doug Pitcairn, 1747 Summer Street, Halifax, Nova Scotia, Canada B3H 3A6. Phone: (902) 463-7196.

August 26
Public Stargaze, Richland, Washington. Sponsored by the Tri-City Astronomy Club. Contact: Thomas L. Page, 1725 Birch, Richland, WA 99352. Phone: (509) 946-9803.

August 30-September 3
6th Annual Mount Kobau Star Party, Okanagan Valley, British Columbia. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

September 1-4
7th Annual Eastern Iowa Star Party, Maquoketa, Iowa. Sponsored by the Quad Cities Astronomical Society. Contact: Dana Taylor, P.O. Box 3706, Davenport, IA 52808. Phone: (319) 322-2557.

September 8-10
Italian Amateur Astronomers Union, Rome, Italy. Held at the Palazzo della Cancelleria, Piazza della Cancelleria. Sponsored by the Roman Amateur Astronomers Association.

September 9
STARCONN '89, Wesleyan University, Middletown, Connecticut. Sponsored by the Astronomical Society of Greater Hartford. Contact: Gengras Planetarium, 950 Trout Brook Drive, West Hartford, CT 06119.

September 20-23
Le Ciel et L'Espace, Aniane Observatory, Montpellier, France. Contact: Bernard Pellequer, Astronomical Observatory, BP 14, 34150, Aniane, France.

September 22-24
3rd Annual Whirlpool Star Party, Birr, County Offaly, Ireland. Sponsored by the Limerick Astronomy Club. Contact: Tony O'Hanlon, 54 Ballycannon Heights, Meelick, County Clare, Republic of Ireland.

September 27-October 1
6th Annual Okie-Tex Star Party, Lake Murray State Park, Ardmore, Oklahoma. Sponsored by the Oklahoma City Astronomy Club. Contact: Oklahoma City Astronomy Club, P.O. Box 21221, Oklahoma City, OK 73156.

September 29-30
Hidden Hollow, Warren Rupp Observatory, Mansfield, Ohio. Sponsored by the Richland Astronomical Society. Contact: P.O. Box 653, Ashland, OH 44805.

September 29-30
1989 Iowa Convention of Amateur and Professional Astronomers, Ames, Iowa. Hosted by the Ames Area Amateur Astronomers and the Iowa State University Astrophysics Group. Contact: John Burnett, 1214 Curtiss Avenue, Ames, IA 50010.

September 29-October 1
I.A.P.P.P. Conference, Wichita, Kansas. Photoelectric photometry, variable stars, and data collection featured. Contact: Thomas L. Burgin, 2101 Rosalie, Wichita, KS 67207. Phone: (316) 685-0518.

September 29-October 1
Stella-Della-Valley III, Ottsville, PA. Sponsored by the Bucks-Mont Astronomical Association and the Mideast Region of the Astronomical League. Contact: Connie Beck, Open Gate Farm, RD 2, Box 261, Perkasie, PA 18944.

September 30-October 1
5th Annual Blue Ridge Parkway Regional Stargaze, Part One, Julian Price Park, North Carolina. Sponsored by the Catawba Valley Astronomy Club. Contact: Greg Kirby, 12 East Street, Granite Falls, NC 28630. Phone: (704) 396-7656.

Please submit announcements four months before the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. □

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Readings and Resources

The Peculiar Pulsar (page 20)

The Supernova Story by Laurence A. Marschall, (Plenum Press, 1988). A book for the general reader on supernovae and supernova 1987A in particular.

"Submillisecond Optical Pulsar in Supernova 1987A," by J. Kristian, *et al., Nature*, March 16, 1989. The paper announcing the discovery of the pulsar.

Supernova 1987A in the Large Magellanic Cloud, edited by Minas Kafatos and Andrew Michalitsianos, (Cambridge University Press, 1988). Proceedings of a scientific workshop on 1987A held at George Mason University in 1987.

Mars and Phobos (page 28)

"Soviet *Phobos* Mission to Probe Moons of Mars" by Donald Robertson, ASTRONOMY, November 1987. A profile of the *Phobos* mission.

The Grand Tour (page 44)

Journey into Space: The First Three Decades of Space Exploration by Bruce Murray, (W. W. Norton & Company, 1989). A comprehensive history of America's space program that weaves together the workings of politics and science.

JPL and the American Space Program: A History of the Jet Propulsion Laboratory by Clayton R. Koppes, (Yale University Press, 1982). Documents the bumpy history of the Jet Propulsion Laboratory from the 1930s through *Voyager*.

Astrophotos the Easy Way (page 70)

Astrophotography for the Amateur by Michael Covington, (Cambridge University Press, 1985). A great book to get you started in astrophotography.

Autumn's Galaxies (page 78)

Deep Sky Observing with Small Telescopes by David J. Eicher and the editors of *Deep Sky*, (Enslow, 1989). An observing manual for backyard observers with an extensive chapter on galaxies.

Observing Handbook and Catalogue of Deep-Sky Objects by Christian Luginbuhl and Brian Skiff, (Cambridge University Press, 1989). A compilation of data and observations of deep-sky objects made with medium and large telescopes.

Recording the Sky (page 86)

An "astrovideo sampler" is available for VHS videocassette players. The tape contains footage of Jupiter, Mars, and an occultation of Venus. For more information, contact David Brewer, P.O. Box 295, Lake Haven, FL 32744. ☐

CREDITS

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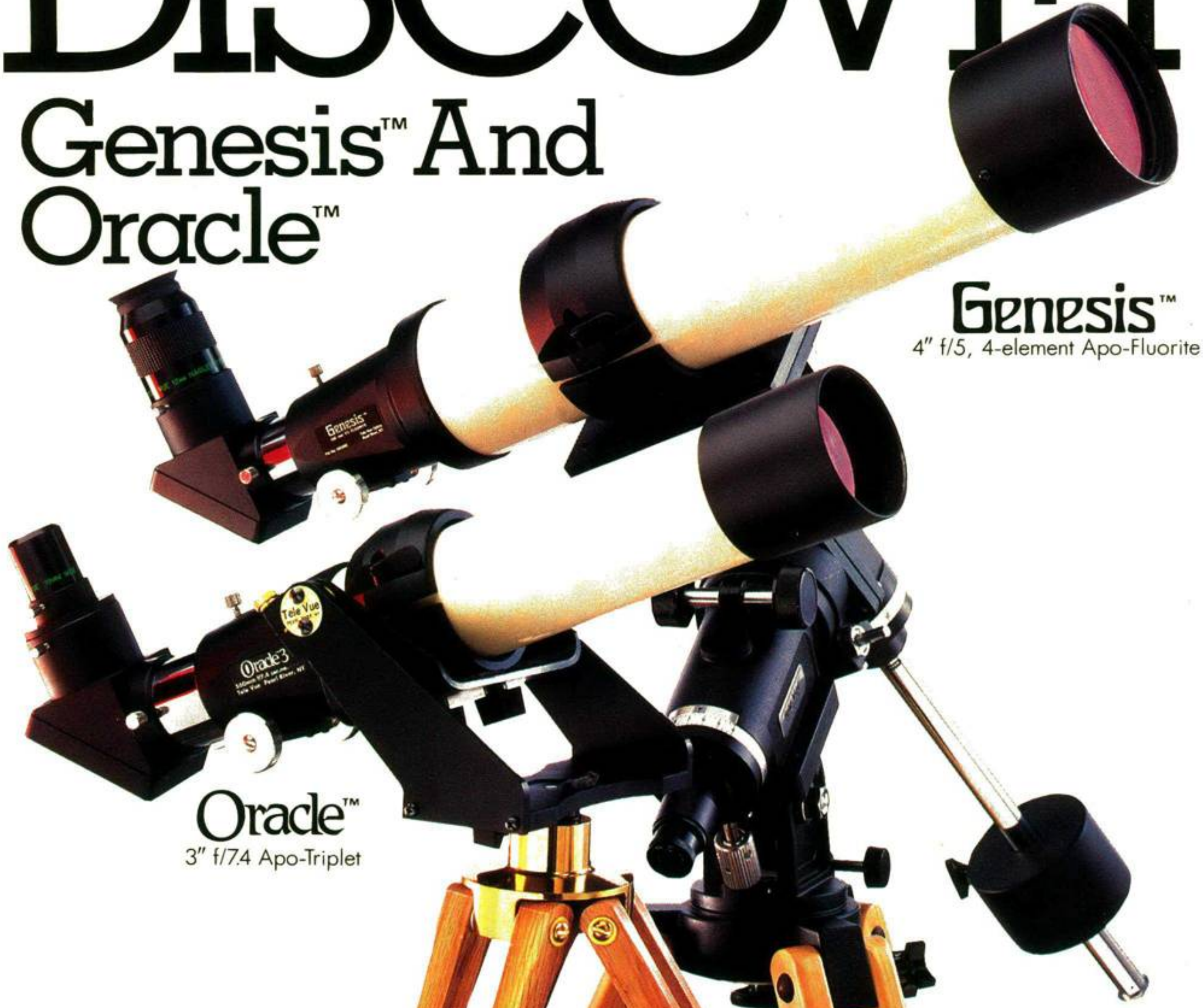

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